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Public perception on the state of air quality in Malta

Nikolas Cassar
James Madison University

PUBLIC PERCEPTION ON THE STATE OF AIR QUALITY IN MALTA

NIKOLAS CASSAR

MSc. in Sustainable Environment Resources Management

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Special committee directing the thesis work of Nikolas Cassar

Mr. Mark Scerri	Date
Dr. Charles Galdies	Date
Dr. Jonathan J. Miles	Date
Dr. Joel Azzopardi	Date
Dr. Eric Maslen	Date

Received by The Graduate School

Date

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NIKOLAS CASSAR

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Dedication

To my family,

for their everlasting support, patience and love

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Declaration

This is to declare that this thesis is an original and unpublished study carried out by the undersigned and is presented to the University of Malta and James Madison University for the first time as part of the requirements for the degree of Master of Science in Sustainable Environment Resources Management and Integrated Science and Technology.

Nikolas Cassar

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ANOVA	Analysis Of Variance
AOT40	Accumulated Ozone Exposure over a threshold of 40 Parts Per Billion
AQ	Air Quality
C_6H_6	Benzene
EC	European Commission
EEA	European Environment Agency
EOTCP	European Ozone Transport Commission Program
ESRI	Environmental Systems Research Institute
EU	European Union
GIS	Geographical Information Systems
IBM	International Business Machine Corporation
IRB	Institutional Review Board
IWD	Inverse Weighing Distance
MARPOL	Marine Pollution Convention
MEPA	Malta Environment and Planning Authority
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NSO	National Statistics Office
O_3	(Ground/Tropospheric/Surface) Ozone
$PM_{2.5}$	Particulate Matter 2.5
PM_{10}	Particulate Matter 10
SPSS	Statistical Package for Social Sciences
UNLRTAP	United Nations Convention on Long-Range Transboundary Air Pollution
VOC	Volatile Organic Compound
WHO	World Health Organisation

Abstract

Public perception on the state of air quality is an unclear and hazy concept whereby every individual has different opinions and views. In fact, the state of air quality is a major concern in many countries, including in Malta. This problem arises from the emissions of a number of pollutants to the atmosphere from a host of processes such as the combustion of fuel to generate electricity and the internal combustion engines to manoeuvre cars. Amongst these pollutants, there are benzene and nitrogen dioxide, which are very hazardous since they cause problems related to human health and contribute in the formation of ground ozone. The levels of these pollutants are continuously being measured by the Malta Environmental and Planning Authority by means of diffusion tubes distributed in various localities. This competent authority was appointed by the 2008 Directive on Ambient Air Quality and Cleaner Air for Europe, which also set up annual limits for the atmospheric pollutants. This research study aims to analyse the actual diffusion tube readings of benzene and nitrogen dioxide levels in Malta and their distribution trends along the island throughout the previous decade. This would eventually be compared with the opinions perceived by the public on the state of air quality collected by questionnaires by using appropriate statistical tests.

Keywords: Public perception, state of air quality, benzene, nitrogen dioxide, air pollution, Malta.

1 Introduction

Air pollution is a major environmental and health concern in many developed and developing countries (Liaquat *et al*., 2010; Kastner *et al*., 2013). This issue mainly results due to the accumulation of contaminants which end up in the atmosphere from a host of natural and anthropogenic processes. However, studies have shown that anthropogenic-induced air pollution is more dominant than the natural induced one. Anthropogenic air pollution is mainly due to fuel combustion processes in order to meet the people's demand for energy (Büke & Köne, 2011). There are various fuel combustion processes, such as vehicular transport, energy production in power plants, industrial processes and residential heating (Chan & Jian, 2013). All of these sources seem to differ in such a way that they release different types and amounts of air pollutants into the atmosphere.

Benzene and nitrogen dioxide are two types of air pollutants which are very hazardous. In fact, they are known to be a major concern[1], amongst many European countries, including Malta. These two air pollutants are also released by the sources mentioned here above. In fact, the European Environment Agency (2013b) gives an account of the recent percentages of these air pollutants emitted by specific sectors within most of the European countries, amongst which are:

- energy generation, which releases 21% of nitrogen dioxide and 10% of volatile organic compounds;
- road transport , which emitts 40% of nitrogen dioixide and 14% of volatile organic compounds; and
- domestic sources, which is responsible for 14% of nitrogen dioxide and 15% of volatile organic compounds.

[1] Nitrogen dioxide levels are a concern due to the difficulties in meeting the limit value. On the other hand, benzene levels are slightly less difficult to achieve.

In addition, the accumulation of such hazardous gases can cause a number of negative effects, which had been largely reported amongst European countries (EEA, 2012). Poor air quality due to benzene and nitrogen dioxide is causing an increasing global awareness since it is triggering numerous human health problems (Pascal *et al*., 2013). In fact, many researchers have mentioned that this issue is largely causing severe respiratory-related health issues which could be life-threatening (Gill *et al*., 2011; Solomon, 2011). Pope *et al*. (2009) also state that there have been numerous cases where these two pollutants affected human morbidity and mortality[2]. Benzene and nitrogen dioxide can also react together in the presence of light and high temperatures to produce ground ozone (Kulkarni *et al*., 2011). This resultant pollutant can cause health impacts, however it also associated with loss of vegetation (Augustaitis *et al*., 2010; Benham *et al*., 2010). This can lead into economical crises and disturbances within ecosystems (Bell *et al*., 2007).

The European Union had published a number of multilateral directives to prevent such problems from happening. One of these directives is Directive 2008/50/EC on ambienet air quality and cleaner air for Europe, which sets limit values on a number of ambient air polluntants. In fact, it sets up an annual limit value of 5 $\mu g/m^3$ for benzene and another annual limit value of 40 $\mu g/m^3$ for nitrogen dioxide. Furthermore, it also establishes a threshold of an eight-hour average value of 120 $\mu g/m^3$ for ground ozone. The said directive is trying to achieve these goals by 2020. The aim is to improve the regional state of air quality. However, in order to accomplish these targets, the parties bound by the directive need to have a competent authority to monitor the level of air pollutants within their jurisdiction. Malta's responsible competent authority is the Malta Environmental and Planning authority (MEPA), which measures the levels of air pollutants by means of diffusion tubes. These are widely distributed along the Maltese islands and they monitor various air pollutants, including benzene and nitrogen dioxide.

[2] It is important to point out that benzene is mostly associated with carcinogenic effects, whereas nitrogen dioxide is mainly related with respiratory health impacts.

It appears that public perception on the state of air quality of a particular area varies from one indivual to another (Slovic *et al.*,1980) and in fact, it is a controversial subject whereby various people have different opinions. Bickerstaff and Walker (2001) add on that generally, public perception is derived from diverse experiences encountered within the physical, socio-cultural world and is often affected by media coverage and other secondary information. Moreover, a large number of people have a habit of perceiving the disintegration of air quality with road-transport and severe respiratory health problems (Saksena, 2007), as is the case in Malta. Questionnaires are essential in order to assess and measure public perception, which is going to be the case in this research study. Through feedback from the survey, one will be able to note how much the Maltese citizens are aware about the state of air quality.

The hypothesis of this research study will be to check whether there is a relationship between the spatial distribution of air pollutants gathered from the diffusion tubes and the public perception on the state of air quality in Malta collected from the respondents who answered the questionnaire. Chapter 1 deals with a general introduction and background on air quality. A detailed description of the air quality in relation to the nature of benzene and nitrogen dioxide as air pollutants is given in Chapter 2. In this part, the sources and resultant impacts of these two hazardous pollutants shall be discussed. This will be followed with a detailed overview of the present legislation which set limitations for the amount of these two air pollutants and a detailed description on how public perception is formed. Finally, this chapter shall discuss how all of these are applicable on the island of Malta. A step by step procedure which explains the method of study is outlined in Chapter 3. This chapter gives a description of the collection and analysis for both data gathered from the diffusion tubes and those gathered from the questionnaires. The fourth chapter consists of the objective analysis by comparing both actual diffusion tube data and perceived data from the surveys, which is followed by a discussion of the analysis made. In Chapter 5, the analysed data is summed up and certain recommendations for a possible reform will be made.

2 Literature Review

2.1 Introduction

"Clean air is considered to be a basic requirement of human health and well-being. However, air pollution continues to pose a significant threat to health worldwide" (WHO, 2006).

Air quality is the condition of the atmosphere at a particular point in time and space (Zhang *et al*., 2012). According to Moodley *et al*. (2011), air is an exteremly essential factor for human wellbeing, especially when it is clean, since it promotes a healthy life span for all living flora and fauna. Air quality is dependent on the emissions of several compounds due to both anthropogenic as well as natural processes (EEA, 2012).

Air pollution can be defined as the emission of substances released by natural and anthropogenic actions which eventually build up in high concentrations and have the potential to cause direct or indirect damages on any living organisms and their surroundings (Jacobson, 2002; Kampa & Castanas, 2008; Monks *et al*., 2009). According to Kampa and Castanas (2008), different types of pollutants classify as follows:

- Gaseous pollutants: primarily end up in the atmosphere through 3 different processes, mainly by:
    - fugitive emissions to the atmosphere e.g. volatile organic compounds (VOCs);
    - direct release to the atmosphere during combustion processes e.g. nitrogen II oxide, nitrogen IV oxide, sulphur dioxide, carbon monoxide; and
    - formed through atmospheric chemical reactions e.g. ozone;
- Persistent organic pollutants: these are a group of chemicals which include very toxic substances such as pesticides, dioxins and polychlorinated biphenyls;

- Heavy metals such as lead, mercury and cadmium which can be produced in a natural and an anthropogenic manner;

- Particulate matter: pollutants consisting of a mixture of suspended particles which vary in size and composition such as particulate matter 2.5 ($PM_{2.5}$) and particulate matter 10 (PM_{10}).

All of the above mentioned pollutants are considered to be a human health concern. In addition they pose social, economical and environmental risks in various regions of the world.[3]

Air pollutants are a major concern both in developing (Liaquat *et al*., 2010) and developed (Kastner *et al*., 2013) nations. Pollutants are emitted in the atmosphere by both natural and anthropogenic processes. According to WHO (2000) certain pollutants released by natural processes are significantly minimal when compared to some anthropogenic ones. Such example of natural air pollutants would include: mineral dust and biological volatile organic compounds released from power and industrial plants (Monks *et al*., 2009); nitrogen oxides from lightning (Monks *et al*., 2009; Wang *et al*., 2013); sea salt aerosols (Bouchlaghem *et al*., 2007) and; smoke, ashes and other substances emitted by volcanic activity (Sawyer *et al*., 2011; Schwandner *et al*., 2013; Tassi *et al*., 2013). On the other hand, anthropogenic emissions end up in the atmosphere from a number of sources generally involving combustion such as road transport, electricity generation, urbanization an residential heating from houses, industries, agricultural practices, quarries, incinerators and waste treatment (Zhang *et al*., 2008b; Kanakidou *et al*., 2011; Gallego *et al*., 2012; Tartakovsky *et al*., 2013; Venturiri *et al*., 2013).

[3] On a historical note, it appears that the issue of air pollution is not a modern one and according to Jacobson (2002), this problem has been present pre the middle ages. Despite this, the problem of air pollution gained importance after two drastic event recorded in history which are the Los Angeles smog (Monks *et al*., 2009) and the 1952 London smog (Fenger, 2009). Both events happened within two metropolitan cities when naxious haze-like conditions developed in the air as a result of anthropogenic acivities involving the combustion of fossil fuels. Martinelli *et al*. (2013) elaborate more on the London smog event which lead to more than 4000 deaths and as a result, it led to more extensive studies by the scientific sectors and became a big political issue amongst various governments.

2.2 Pollutants under study

As pointed out previously, there are various types of pollutants. All of these have different chemical composition properties and different impacts on human health (Kampa & Castanas, 2008). In this research study, only two specific pollutants are going to be addressed. The discussed pollutants are: benzene and nitrogen dioxide. These same pollutants were opted for this study due to their significant contribution in the degradation of air quality, resulting in severe health hazards and posing serious threats to human welfare. Furthermore, both of these air pollutants are precursors of tropospheric ozone, which continue to pose more impacts, especially on vegetation. The trends of these pollutants shall be addressed on a European and Maltese level in this chapter.

2.2.1 Benzene

Benzene is considered to be one of the most important airborne pollutants in the atmosphere (Protano *et al*., 2012) since it is a type of volatile organic compound which is very toxic (Bono *et al*., 2010) and very hazardous to humans beings (Di Gennaro *et al*., 2011). The basic structure of benzene contains a ringed, hydrocarbon chain of six atoms of carbon, whereby each atom is bonded with a hydrogen atom and thus, having a chemical formula: C_6H_6 (Figure 2.1). The IARC Monograph (2012) illustrates the said volatile organic compound as being clear, colourless, highly flammable and slightly soluble in water. In addition, benzene is generally considered hazardous to human beings in the following circumstances:

- once it is inhaled through breathing (WHO, 2010); or
- absorbed by the dermis (Anon, 2012).

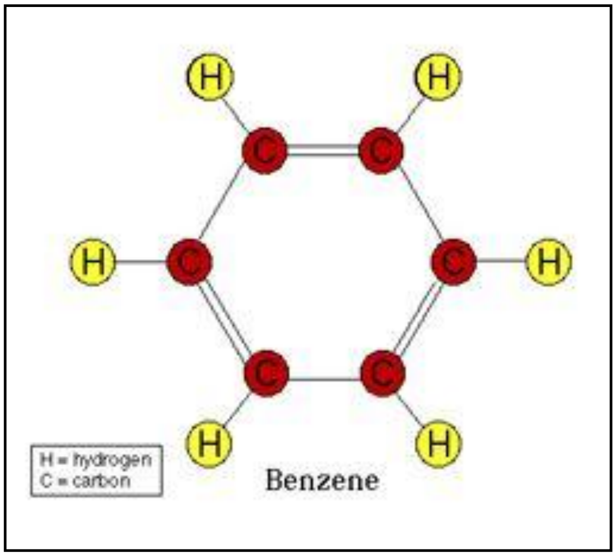

Figure 2.1. - Chemical Structure of benzene (Source: WHO, 2013).

2.2.2 Sources of Benzene

There are many sources which emit this hazardous substance in the atmosphere and in fact, Bono *et al*. (2010) and Weisel (2010) give an account of several benzene sources, amongst which are: transportation, power plant activities, industrial and domestic heating, agriculture, oil-refining and petrol handling, distribution and storage. However, a lot of authors, including and Han and Naeher (2006) and Di Gennaro *et al*. (2011) highlight that road motor vehicles are the top emitters of benzene in the air[4]. On the other hand, there are other authors such as Fernandez-Somoano *et al*. (2011), who argue that industrial activities are more prone to benzene-induced air pollution such as industries involving wood burning. In the previously mentioned instances, one may note that gasoline is used, which is a product of benzene-rich crude petrolluem (WHO, 2010). Hence, all combustion processes which involve the burning of petrolluem, including incomplete combustion (EEA, 2012), all contribute significantly to the release of benzene in the atmosphere.

[4] Waked and Afif (2012) state that the transport sector is the top contributor of benzene air pollution in the Middle East, namley in Lebanon. This country is a developing nation which had evolved tremendously over the past decade and as a result, traffic congestion increased due to the fact that people were being reluctant to use public transport. In addition to this, Tolba and Saab (2008) state that motor transport in the Middle East region has accounted for approxiamtely 75% volatile organic compound emissions.

Another source is cigarette smoke. Hays *et al*. (2012) states that this ubiquitous environmental substance is also dominantly present in cigarette smoke. In fact, tobacco exposure is said to be a significant contributor of benzene in the atmosphere (Johnson *et al.*, 2007; Weisel, 2010). The same authors elaborate that smokers inhale approximately ninety percent of benzene emitted by tobacco smoking and thus, making the other ten percent inhaled by non-smokers through passive smoking. Furthermore, in accordance to WHO (2010), cigarette smoking is contributor which increases the level of benzene within indoor residential air space, which can have a negative effect on people who stay inside a lot such as children. Moreover, Karakitsios *et al*. (2013) add on stating that benzene exposure can lead to very high risks of leukemia.

2.2.3 Benzene trends in Europe

Figure 2.2 displays the emissions of various air pollutants in Europe throughout the previous years. At first glance, one may notice that such emissions have decreased drastically throughout the previous twenty three years. This decrease seems to have occurred mainly due to strict regulating regional measures. These same measures shall considered in a later section. Amongst the all the displayed emission trends, there is the trend of non-methane volatile organic compounds emissions (including benzene) which is marked in dark green. In this situation, there seem to be a decline by 59% (EEA, 2013b). One can point out that the emissions of the said pollutant was of 16,633Gg in 1990, when compared to 2011, it was decreased to 6,848Gg.

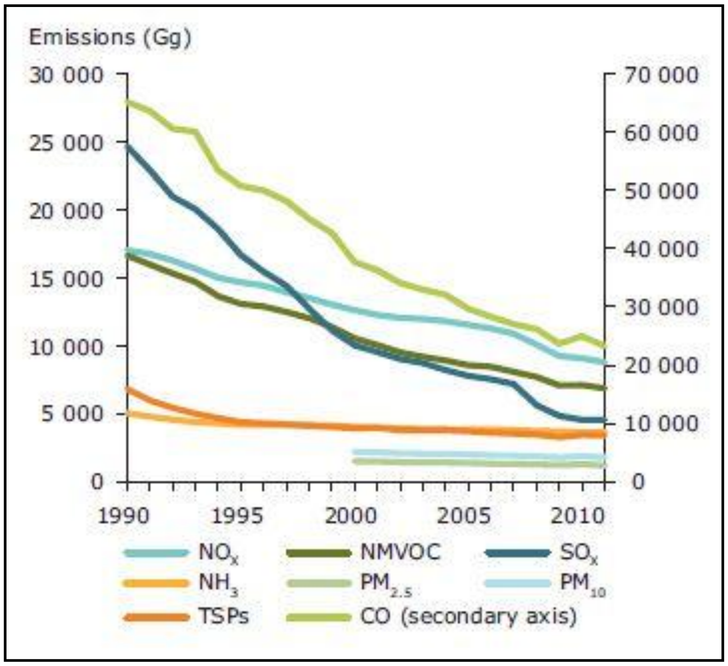

Figure 2.2. - Graph showing emission trends of gaseous air pollutants in EU-27 (Source: EEA, 2013b).

The European Environment Agency (2013b) has given an account on the largest non-methane volatile organic compounds sources and emitters within all the parties of the European Union (EU). Figure 2.3 shows that solvent is the highest contributor of this pollutant and it is the use of these solvents and products, which is responsible for 45% the total emissions. This appears to result from the high content of organic material that is present in the solvent (EEA, 1999). Following the solvent are:

- commercial, institutional and households (15%);
- road transport (14%) ;and
- energy production and distribution (10%).

All the above mentioned benzene sources and emitters, involve the combustion of fossil fuels.

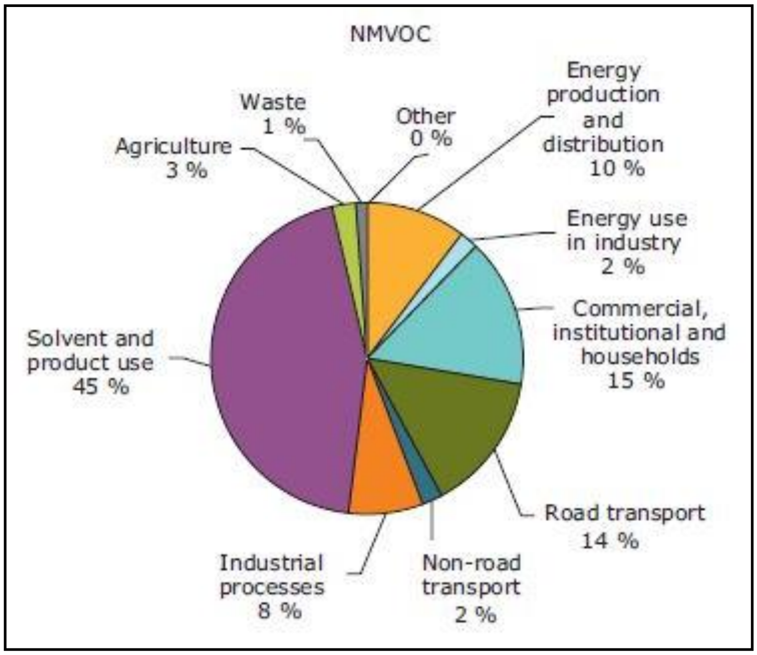

Figure 2.3. - Pie-chart showing the 2011 share of NMVOC emissions by sector group in the EU-27 (Source: EEA, 2013b).

2.2.4 Nitrogen dioxide

Nitrogen oxides are specific type of pollutants which seem to be more dominant in the atmosphere and they appear to be crucial in determining the air quality since studies have shown that they can easily affect human health (Lawson *et al*., 2011; Mead *et al*., 2013). In fact, the World Health Organisation (2006) identifies nitrogen oxides as chemical pollutants which impact the quality of life and mortality rates. This type of pollutant comprises a binary, bonding chain of a nitrogen and oxygen atoms, in which the said atoms can vary in number. Such example of nitrogen oxides would include: nitrogen monoxide (NO) and nitrogen dioxide (NO_2).

For the purpose of this dissertation, only nitrogen dioxide is being considered since it is related with many adverse effects on human health (EEA, 2012) and especially on the respiratory system (Robinson et al., 2013). This substance consists of a nitrogen atom double-bonded with two oxygen atoms, as per Figure 2.4. In nature, nitrogen dioxide is an ubiquitous, light reddish-brown gas which is soluble in water and very strong oxidant

(WHO, 2000; Hesterberg *et al*., 2009; Chen *et al*., 2012). Moreover, Liu *et al*. (2013) describes this gaseous substance as a well-known ambient air pollutant with a pungent and infuriating odour.

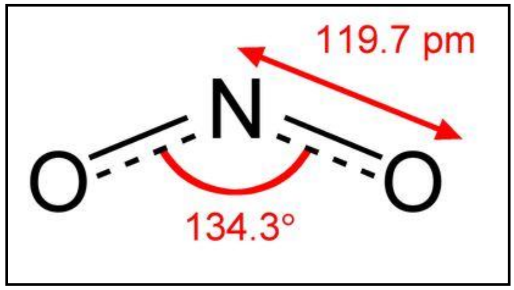

Figure 2.4. - Chemical structure of nitrogen dioxide (Source: Chemistry Reference, 2013).

2.2.5 Sources of nitrogen dioixide

This type of pollutant is emitted in the atmosphere by a number of natural and antropogenic processes. One natural process responsible for this type of gas is lightning activity (Monks *et al*., 2009). In fact, according to Wang *et al*., 2013, lightning produces nitrogen dioxide in the upper and lower tropospheric levels, whereby they act as catalysts to form ozone, which is another ambient air pollutant. This subject will be adressed in more detail further on.

On the other hand, anthropogenic activities would generally include the combustion of fossil fuels and biomass burning (Richter *et al*., 2005). Exhausts produced by combustion of fuel in vehicles seem to contribute significantly to the nitrogen dioxide emissions in the atmosphere (Gilbert *et al*., 2007; Nagendra *et al*., 2007; Robinson *et al*., 2013). Afzal *et al*. (2012) also point out most often, nitrogen dioxide emissions are present within transport gases in very low concentrations[5]. Also, nitrogen dioxide is said to be generated

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[5] A typical example can be seen in the case scenario of the Middle eastern region mentioned previously whereby transport had been found to be responsible for nearly 90% of nitrogen dioxide emissions (Tolba & Saab, 2008; Waked & Afif, 2012). Another similar situation can be observed in the developing Indian

through indoor combustion sources and processes, which would generally including the use of gas-fired appliances, stoves and tobacco smoking (Kattan *et al*., 2007; Kornartit *et al*., 2010).

Furthermore, this compound is also emitted in the atmosphere by non-combustion processes. An example of such processes include the manufacturing of nitric oxide, whereby it undergoes oxidation processes and produces nitrogen dioxide as an end result (Kumar Verma *et al*., 2008). Many scientific studies show that human health is largely affected due to both for short and long term exposures of nitrogen dioxide. This effect may take place in an acute or chronic manner (Wong *et al*., 2005; Lawson *et al*., 2011; Mead *et al*., 2013).

2.2.6 Nitrogen dioxide trends in Europe

It can be observed that nitrogen oxides, including nitrogen dioxide, has decreased significantly in the EU between 1990 and 2011. This is indicated in light blue on the previously shown Figure 2.2. This decline seems to have occurred due to strict EU legislations (EEA, 2013b). The graph displays that in 1990, the level of nitrogen dioxide emission was 17,022Gg, which by 2011, was reduced by 48% to a level of 8,780Gg. The pie-chart in Figure 2.5 shows all the sectors which are responsible for the nitrogen oxide emissions within all EU nations. Road transport is the major source for the highest emission of nitrogen oxides, with a value of 40%. The second top contributor of this pollutant is eneregy production (21%), followed by commercial, institutional and households (14%) and Energy use in industry (13%). As one can note all the previously mentioned sectors involve the burning of fuels and in some way or another, all contribute significantly in the production of nitrogen oxide emissions.

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megacity of Dehli (Nagpure *et al*., 2013). According to Gurjar *et al*. (2004), this metropolitan city is one of the major polluted cities in the world and mainly due to the rapid upsurge of motor vehicles. Nagpure *et al*. (2013) continue to state that this city exhibited an annual vehicular growth of nearly ten percent over the previous decade which as a result, the annual nitrogen dioxide emission from gasoline utilization went up from 3.5 to 4.5 Gg.

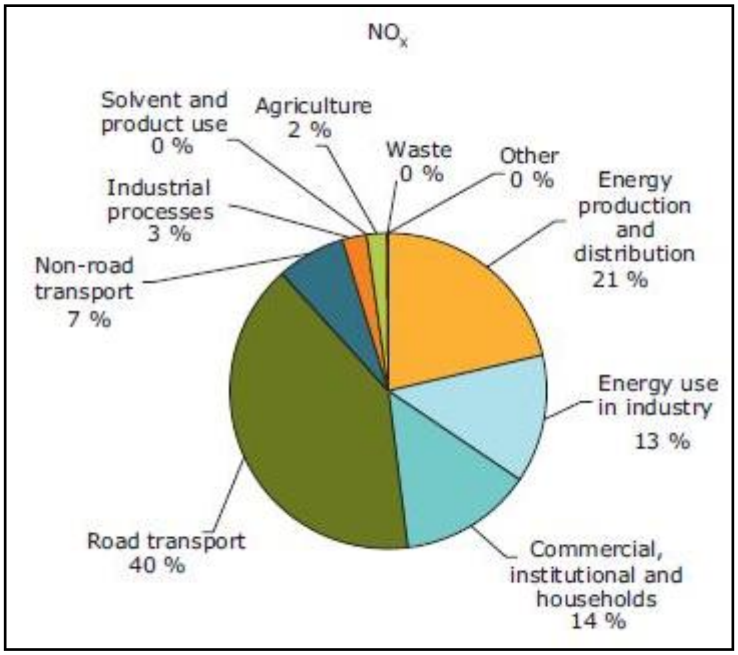

Figure 2.5. - Pie-chart showing the 2011 share of nitrogen oxides emissions by sector group in the EU-27 (Source: EEA, 2013b).

2.3 Resultant impacts

Several researches have shown that air pollution has a number of impacts. In many countries, it seems that human health is the most associated and concerning problem (Pascal *et al*., 2013)**.** In fact, Pope *et al*. (2009) indicate that there are scientific studies which exhibit a clear relationship between air pollution exposure and human mortality and morbidity. Kampa & Castanas (2008) state that human health problems are mainly caused when air pollutants are inhaled, however they can also cause problems if they pentetrate through ingestion and dermal contact. Dhondt *et al*. (2012) add on that every type of health problem is generally caused by a specific type of pollutant or else by a combination of all. There are many critical health problems related to poor air quality, amongst which the folowing: cognitive impairment, nervous system problems, pregnancy problems, early childhood health difficulties and different reproductive and development disorders (Kampa & Castanas, 2008; Bono *et al*., 2010; Coull *et al*., 2011; Estarlich *et al*., 2011; Martinelli *et al*., 2013).

2.3.1 Health impacts of benzene

Exposure to benzene leads to low quality of life due to numerous adverse health effects (Curtis *et al*., 2006; Protano *et al*., 2012). In fact, a number of health professionals have declared and agreed that the current ambient levels of benzene are leading to an increase in morbidity aggrevations and premature mortalities (Vlachokostas *et al*., 2011). Hence, limitations must be set on products and processes which emit this hazardous substance (Di Gennaro *et al*., 2011). Studies also have shown that benzene exposure is more effective on infants, small children, foetuses and pregnant women. This happens because thementioned volatile organic compound can easily interfere with the immune, respiratory, reproductive, digestive, nervous systems. Also, it can easily disrupt the developemental stage of cells, tissues and organs (Schwartz, 2004). As a result, this would lead to low birth weight, premature birth, asthma and allegeries, cogenital malformation, foetal growth formation and even deaths (Fernandez-Somoano *et al*., 2011).

Once inhaled, benzene diffuses passively through the one-cell thick layers of the alveoli (Buthbumrung *et al*., 2008) and eventually, interferes with metabolic processes which occur naturally in the human body. Ross and Zhou (2010) state that metabolic reactions involving benzene are very complex and have the potential to produce toxic, reactive metabolite products[6] and as a result, lead to DNA damages[7] (EEA, 2012). In fact, Lindsey Jr *et al*. (2004) state that mammalian cells are extremely prone to DNA mutations, insertations, deletions, bio-chemical strand breaks, sister chromatid exchange and apoptosis in the presence of this volatile organic compound.

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[6] According to Sarma *et al*. (2011), benzene is generally metabolized in the liver by a specific enzyme named Cytochrome P450 2E1 (CYP2E1) to produce phenol, benzine epoxide and trans-trans-muconaldehyde (Hays *et al*., 2012). Phenol undergoes a series of hydroxylation processes in which three further products are produced: hydroquinone, catechol and 1,2,4-benzenetriol. The prior two resultant metabolites products are then further transformed into 1,4-benzoquinone by oxidative enzymes situated in the bone marrow (Synder, 2004). These resultant reactive metabolites are considered to be more toxic than the parent volatile organic compound (Vlachokostas *et al*., 2011).

[7] In the metropolitan city of Bangkok, young urban school pupils were having developing problems due to oxidative DNA damages which were resulting high exposure of benzene (Buthbumrung *et al*., 2008).

Disturbances of the geneteric materials of the cell can lead to cancers. In accordance to Di Gennaro *et al*. (2011), benzene ranks the top list of hazardous carcinogenic compounds. Protano *et al*. (2012) states that this substance has been known by the International Agency for Research on Cancer (IARC) as one of the main contributor for cancer in the human body since 1982. In some instances, benzene is known to cause leukemia (Hays *et al*., 2012), which is a type of cancer situated in the blood, and in some cases, even on the bone marrow. In fact, Zhang *et al*. (2010) highlight that benzene exposure can possibly lead to numereous types of leukemia, namely: acute myeloid leukemia, myelogenous leukemia, myeloidisplastic syndrome, lymphocytic leukemia and non-hogkin lymphoma. However, each one depends on whether benzene exposures are either too low or too high (Shen *et al*., 2008; Synder, 2004). Moreover, the risk of getting this type of cancer in the blood is not the same for every person since, it also depends on other contributing factors. In addition, Young *et al*. (2006) show that due to the infererence of the development of white blood cells in the bone marrow, the immune system will be affected since there would not be any defense mechanisms against harmful microbes[8].

2.3.2 Health impacts of nitrogen dioxide

Studies show nitrogen dioxide can cause genotoxicity and DNA damages to humans during short term exposure when its concentration is at a range of 20.3-20,300 $\mu g/m^3$ (Koehler *et al*., 2011). Recent studies have shown that DNA strands in varous internal organs were damaged upon the inhalation of nitrogen dioxide, hence showing that this gaseous pollutant is truly a systematic genotoxic agent *in-vivo* (Han *et al*., 2013). Nitrogen dioxide is also capable of altering the normal processes involved in gene expression and functions (Evans *et al*., 2004; Oh *et al*., 2011), and can therefore effect the epigenome, a genome in the DNA which controls the gene expression, development,

[8] Hays *et al*. (2012) and Sarma *et al*. (2011) draw attention to that benzene metabolites can cause aplastic anemia as well, which according is a disease that damages the bone marrow and a result, it fails to produce enough white blood cells. Moreover, as stated by Montane *et al*., (2008), this is a very severe condition however its occurance is very rare.

differentiation of tissue, tumorigenesis, and transposable elements suppression (Bernstein *et al*., 2007). DNA strand breaks were visible when the concentrantion of nitrogen dioxide was at about 20,300 μg/m^3 as a result of an *in-vitro* experiments (Koehler *et al*., 2011). Han *et al*. (2013) continues to elaborate that this issue leads to mutation and potentially, it can lead to cancer and premature aging, although, Koehler *et al*. (2011) argue that this remains a matter of discussion since there are still no definite results.

Short-term exposures of nitrogen dioxide can possibly trigger lung disfunction (Valero *et al*., 2009; Koehler *et al*., 2010). Kornartit *et al*. (2010) point out that short term exposure of nitrogen dioxide with concentration of 5,060-15,200 μg/m^3 can cause slight changes in lung functions amongst humans, whereas if the concentration is slightly lower (≈405-608 μg/m^3), it can have adverse effects on asthmatics[9]. High nitrogen dioxide concentrations can also be a burden on human health (Smith *et al*., 1996). Switalla *et al*. (2010) state that high concentrations between 203,000 and 1,015,000 μg/m^3 can also cause lung damages such as lung cellular changes, respiratory inflammations, lipid peroxidation and membrane damage on the epithelial tissues lining the alveoli of the lungs (Koehler *et al*., 2010). In addition, this correlation between respiratory problems and nitrogen dioxide exposures still lacks information and in fact, Steinvil *et al*. (2008) concludes that there is the need for more research in this field of interest which should be based with good methodological techniques.

Another health problem related to nitrogen dioxide is ischemic stroke, which generally happens by long-term exposure of the said pollutant (Andersen *et al*., 2012; Yorifuji *et al*., 2013). Ischemic stroke occurs when there is a disturbance in the supply of oxygen within the blood flowing to the brain tissue which as result leads to the dysfunctioning of

[9] Another experiment was tested on rats whereby they were exposed to approximately 10,100 μg/m^3 of said gaseous pollutant for four hours and it resulted that there had been morphological alterations in the respiratory tract (Switalla *et al*., 2010). The authors elaborate further by stating that such alterations would involve the rapturing of the epithelial cells of alveoli which causes pulmonary edema.

the brain[10]. Klijn and Hankey (2003) also state that ischemic stoke is one of the leading causes of death worldwide and furthermore, it has also been reported that it leads to disability, with a high incidence of approximately 0.2% of the total global population. In addition, long-term exposure of nitrogen dioxide does not only effect the lung and the brain but also may result into other harsh, problematic impacts, particularly in the spleen, liver, kidneys and blood (Lawson *et al*., 2011). This mainly happens mainly due to the ability of nitrogen dioxide to diminish the level of oxygen transported in the body (Mead *et al*., 2013).

2.3.3 Tropospheric ozone as a result of benzene and nitrogen dioxide

Tropospheric ozone usually occurs naturally in small concentrations in the troposphere, which is the lowest level of the Earth's atmosphere. However, the concentrations of this pollutant may be increased by anthropogenic emissions which can cause many severe problems in humans and vegetations (Beig *et al*., 2008; Zhang *et al*., 2008a). Tropospheric ozone is a very strong oxidant which consists of three bonded atoms of oxygen. In addition, this chemical is also considered as a noxious, colourless gaseous pollutant (Butler *et al*., 2011; Sousa *et al*., 2013).

Tropospheric ozone is produced by a photochemical chain reaction processes involving the oxidation of volatile organic compounds, such as benzene, and nitrogen oxides, which include nitrogen dioxide (Stedman & Kent, 2008; Kulkarni *et al*., 2011). This is indicated better by Figure 2.6 (EEA, 1998). The energy needed for the formation of tropospheric ozone comes from electromagnetic waves having large wavelengths. These waves manage to penetrate through the stratosphere, especially during hot and sunny days (Atkinson, 2000; Arsić *et al*., 2011). Moreover, it seems that the formation of the said

[10] Zhu *et al*. (2012) describes how nitrogen dioxide has the ability to reduce the level of oxygen in the blood which as a result effects the balance of two specific enzymes in the endothelium cells lining the blood vessels of the brain tissue: endothelin and endothelium nitric oxide synthase. This imbalance leads to blood flow diminishing (Leung *et al*., 2009) and thus cause inflammation. At this point, inflammation-related enzymes such as tumour necrosis factor-α are accumulated and overproduced and these lead to the probability of increased blood coagulation, thrombus formation, tissue injury and hence, ischemic stroke (Zhu *et al*., 2012).

pollutant is also affected by the types of volatile organic compounds present, since each one has specific structures and different reactive processes which occur in various spaces and timescales (Arsić, et al., 2011; Butler *et al.*, 2011).

	$VOC + OH + O_2$	®	$RO_2 + H_2O$
	$RO_2 + NO + O_2$	®	$NO_2 + HO_2 + CARB$
	$HO_2 + NO$	®	$NO_2 + OH$
	$2(NO_2 + hv + O_2$	«	$NO + O_3)$
net:	$(NOx + OH +)\ VOC + 4O_2$	®	$2O_3 + CARB + H_2O\ (+ NOx + OH)$

VOC stands for volatile organic compound and CARB for carbonyl compounds, which play the role of hydrocarbons in further oxidation steps. OH and HO_2 are short-lived radicals which play an important role in the ozone formation process.

Figure 2.6. - The photochemistry of ozone formation in simplified form (Source: EEA, 1998).

Westmoreland *et al*. (2007) stated that this pollutant has the potential to react with freely abundant nitrogen monoxide and rapidly produce secondary nitrogen dioxide, as per equation:

$$NO + O_3 \rightarrow NO_2 + O_2.$$

Thus, more ozone formation will result into more production and high emissions of nitrogen dioxide (Robinson *et al*., 2013) which would continue to cause a problematic reinforcing feedback mechanism.

2.3.4 Tropospheric ozone trends in Europe

In Europe, tropospheric ozone (O_3) formation is also caused by the reaction of the same precursors mentioned previously with the aid of sunlight. However, it seems that in European urban areas, tropospheric ozone is mainly induced by volatile organic compounds, whereas in rural areas, the same pollutant is enhanced by nitrogen oxides. It seems that both situations cause a regional problem since ground-ozone get transported around the continent by means of aeolian processes (EEA, 1998). Nevertheless, the same agency recently estimated that ozone levels in rural areas are higher than in urban areas (EEA, 2012). This is due to the fact that tropospheric ozone within the urban areas is constantly and rapidly reacting with abundant nitrogen oxides emitted from anthropogenic sources, i.e. by fuel burning.

Moreover, the European Environment Agency (2012) states that ozone concentration may vary with two particular parameters which are latitude and altitude. This can be observed on Figure 2.7, which displays the latest ozone concentration readings amongst various European countries. This map shows that the the concentration of tropospheric ozone is relatlively higher around the Southern European and Mediterranean regions. This occurs due to the lengthy hours of strong sunlight and high temperatures which aid photochemical rection to produce surface ozone (Figure 2.6).In addition, mountainous areas such as the Alps, Apennines and Pyrenees, show surface ozone concentrations of more than 140 μg/m^3. This mainly occurs due to the fact that tropospheric ozone gets depleted easily in low elevated ares due to surface depositing processes and titration reactions which are not present at high altitudes.

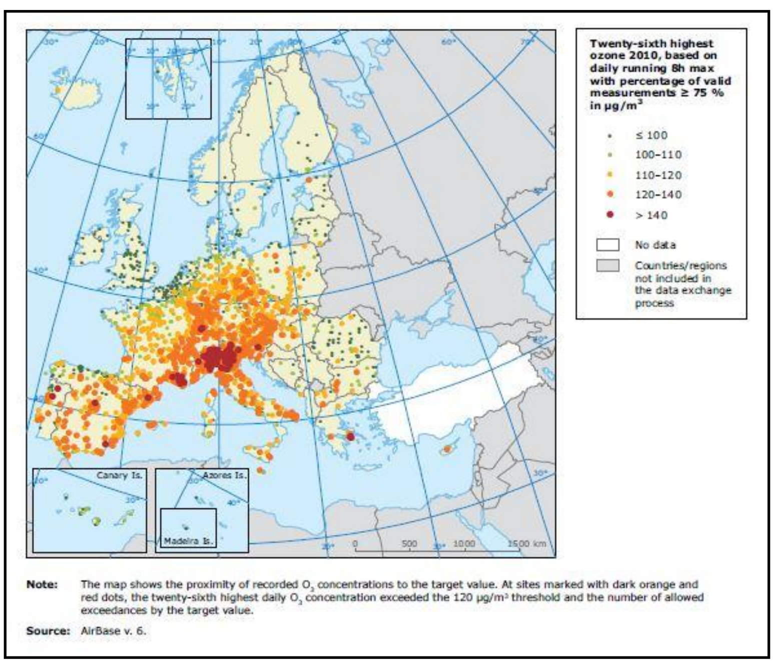

Figure 2.7. - Twenty-sixth highest daily maximum 8-hour average O_3 concentration recorded at each 2,107 ozone-monitoring station in 2010 (Source: EEA, 2012).

According to the European Environment Agency (2012), no clear association is observed between the annual average concentration of ground ozone and the emissions of its precursors, i.e. VOC and nitrogen dioxide emissions, within the European continent. This might be due to following two reasons, namely: the upsurge of intercontinental transport of surface ozone and the changes in certain external factors which cannot be controlled and regulated by EU measures such as climate shift, plant-generated volatile organic compound emissions, natural forest fires and meteorological conditions. In fact, The European Environment Agency (2013a) reports that throughout the summer of 2012, ozone levels within some countries were considerably high due to high insolation and temperatures. Nevertheless, other European countries seemed to have succeeded in diminishing of the anthropogenic emissions throughout the previous years in such a way that the number of peak tropospheric ozone concentration values was minimised due to the good use of ozone-abating titration techniques (Szopa & Hauglustaine, 2007; Zanis *et al.*, 2011; EEA, 2012). The Agency points out that pollution by ground ozone is a topic of discussion amongst many European competent authorities which favour additional mitigation efforts.

2.3.5 Health impacts of tropospheric ozone

Tropospheric ozone has the potential to cause adverse human health impacts and increases hospital admissions, emergency department visits and medical uses (Yang *et al.*, 2012; Sousa *et al.*, 2013). There has been numereous cases were people, mostly children and elderly people, had been reported to suffer from such effects, amongst which are impaired lung tissues, reduced lung function and asthma (Salvi, 2007; Sousa *et al.*, 2013). In fact, in accordance to Zanobetti and Schwartz (2008), as cited by Arsić *et al.* (2011), ground-level ozone has a lot of severe, chronic impacts on the respiratory organs. This results into an increased mortality rate in many countries, which in turn is leading to high death rates.

Sousa *et al*. (2013) states that asthma is caused by exposure of tropospheric ozone and it is generally detectable due to its symptoms[11]. In fact, this condition is considered one of the most associated health problems that is triggered by surface ozone (Salvi, 2007). According to Sousa *et al*. (2013), children and infants are more prone to asthma due to the fact that they do not have a fully developed immune system. Furthermore, this condition is considered the commonest in Europe in which it had been increasing considerably throughout the previous decade (Sousa *et al*., 2011).

As stated hereabove, the European Environment Agency (2012) reports that many European citzens suffer similar difficulties and problems due to the exposure of the said pollutant, especially throughout the summer months, when sunlight is largely abundant and temperature are generally high. Furthermore, as stated before, the increase of ozone-related health problems in Europe is very common within the countrysides, on high topographic grounds and within the Southern Mediterranrean region. A similar example can be seen within various European countries, whereby in the year 2003, they experienced an unusual heat wave that lasted about a fortnight, and as a result, high levels of ground ozone were generated (Arsić *et al*., 2011; Zanis *et al*., 2011). Tropospheric ozone-measuring experiments were conducted in number of European nations which showed that their hourly concentrations were above 50–60 $\mu g/m^3$ (Gryparis *et al*., 2004). Vautard *et al*. (2005) also highlights that similar concentrations were reported in France. In this case, over 15,000 fatalities occured by the heat stress on vulnerable people. The European Environment Agency (2012) points out that presently, the mortality rates in Europe are constantly on the increase due to conctact with high concentrations of tropospheric ozone.

[11] Such symptomps includes dyspnoea, wheezing, chest tightness, repeated coughs, bronchoconstriction, inflamed epithelial cells and excess mucus in the trachea (Alvim-Ferraz *et al*., 2005; Trasande & Thurston, 2005).

2.3.6 Impacts on vegetation

Air pollutants seem to affect vegetation loss (Benham *et al*., 2010). Nitrogen dioxide being a contributor of acid rain, eventually ends up in the soil via precipitation. Once it enters the soil, the nitrogen dioxide oxidises in such a way that it produces hazardous resultant compounds such as nitric acid which increases soil fertility (Felzer *et al*., 2007). This leads into an alteration of enzyme activities present in the soil and plant which can lead to plant growth deficiency.

Moreover, as mentioned previously, nitrogen dioxide is a precursor of tropospheric ozone which is very dominant within non-urban regions such as the countryside and agricultural areas. This resultant pollutant is documented to have more chronic effects on the plant tissue, which can either be exterior and visible to the naked eye, or else interior, i.e. concerning changes in the internal physiology (Fagnano *et al*., 2009). Such visible impacts can be the alteration in the chlorophyll pigment and chlorosis, which generally are the aftermath of low ground ozone exposure (Felzer *et al*., 2007). Furthermore, the same authors state that high exposure of the said pollutant can lead to other chronic exterior impacts on the plant such as flecking and stippling. In contrast, the interior physiological effects of plant would commonly include cellular degradation, decreased capacity of photosynthesis and stomatal conductance change, which in turn interferes with plant growth (Felzer *et al*., 2007; Furlan *et al*., 2007; Benham *et al*., 2010).

It seems that ozone causes more problems in plants compared to nitrogen dioxide, and in fact, according to Adams *et al*. (1986), this pollutant is responsible for 90% of vegetation damage and loss. This has been proved by numerous lab experiments and fieldworks which showed results that not every vegetative plant is affected the same way. Having said this, some plants exhibited no impacts at all. One specific study shows that an exposure of 42,300 $\mu g/m^3$ ozone concentration led to a minimisation of photosynthesis within three different types of plants (Reich, 1987). The author noticed a 7% photosynthesis reduction amongst conifers, a 36% photosynthesis reduction in hardwoods and another 73% photosynthesis diminishing amongst agricultural crops. While conifers and hardwood exhibit very minimal growth reductions, in comparison the growth reduction of crops is very high. This same growth can lead to adverse negative effects in many national economies if not regulated. As a preventive measure, the European Ozone Transport Commission Program (EOTCP) was set up to study the resultant outcomes of ground ozone by focusing mainly on the its associated processes and impacts on agricultural productivity and the European economy (Felzer *et al*., 2007).

2.3.7 Other resultant impacts

Apart from human health and vegetative impacts, air pollution can cause other direct impacts. Nitrogen dioxide can bind with precipitation to cause acid rain leading to adverse damage to the infrastructure, buildings and monuments (Kumar & Imam, 2013). It also has the potential to corrode stones, especially if it is limestone or sandstone (Inkpen *et al*., 2012). This does not only affect the facade or the structure of establishments, however it can also affect their cultural, aesthetical and historical values (Karaca, 2013). Moreover, acid rain can lead acidification of natural fresh water, which result in eutrophication, algal blooms and loss of aquatic biodiversity.

2.4 Ambient air quality strategies and legislations in Europe

Ambient air pollution can cause harmful effects to human health, reduce plant growth and indirectly, lead to severe economic crisis. Hence, policy and legislation measures are essentially important since they are able to control the level and emissions of air pollutants within a specific geographical location. It is for this reason that in the previous years, the EU had published and implemented a number of measures which help to regulate such pollutants, particularly on the two air pollutants under study: benzene and nitrogen dioxide.

The European Commission formulated a thematic strategy on the regulation of regional air pollution as way back in September 2005 (EEA, 2012). This strategy is one of the seven EU environment strategies resulting from the 2001 Clean Air for Europe Programme (Tuinstra, 2007). This policy sets out a number of long-term goals to all of its Member States and relevant stakeholders so that they can freely develop innovative approaches in such a way that by 2020, the regional air quality would be improved (Totlandsdal *et al*., 2007). Such improvements would generally include the cutting down of ozone-induced acute mortalities by 10%; reduce surplus deposition of acid in woodlands by 74% and in freshwaters by 39%; and minimise eutrophication impacts by 43%. All of these targets aim to achieve a reduction in the major hazardous air pollutants, particularly a reduction of nitrogen oxides and volatile organic compounds by 60% and 51% respectively (EEA, 2012).

Apart from this policy, the European Union took the initiative to issue a number of directives to further continue regulating air pollutant level and emissions. It also sought to improve regional air quality. Such legal instruments are designed to set goals and limitations for ambient levels, restrict air emissions and control specific emissions released from particular sources (EEA, 2012). Some legislative measures concerning the regulation of benzene, nitrogen dioxide and ground ozone include:

- Directive 1994/63/EC on the control of Volatile Organic Compound VOC emissions resulting from the shortage of petrol and its distribution from terminals to service stations: this legislation aims to regulate VOC emissions released by specific sectors in the EU which involve themselves in the petrol operations, installations, storage, loading and transporting;

- Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants: the target of this legal instrument is to move towards a long-term objective to enhance environmental protection and human health from acidification, soil eutrophication and tropospheric ozone by setting relevant ambient emission caps on ambient air pollutants, which in this case are benzene and nitrogen dioxide;

- Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control): this directive is also responsible to control emissions, including benzene and nitrogen dioxide, which are emitted by industrial processes, agricultural activities and waste treatment facilities; and
- The Euro Standards for road vehicle emissions: these help to regulate atmospheric emissions by setting Euro 4 standards on light-duty vehicles, such as cars and light vans, and applying Euro 5/6 standards on heavy-duty vehicles, which would include buses and trucks (EC, 2012).

The main EU directive seems to be Directive 2008/50/EC on ambient air quality and cleaner air for Europe. This specific Directive is a revision of the Council Directive 1996/62/EC on Ambient Air Quality Assessment and Management (MEPA, 2010b), in which new ambient annual and hourly limits for air pollutants were set up due to recorded adverse health and environment negative effects. Article 1 of the said Directive lays down a number of targets, amongst which is an objection to avoid, prevent or diminish socio-economic and environmental damaging effects in the regional ambient air quality. In order to reach this said objective, Member States are obliged to assign a responsible competent authority to assess, monitor and measure the level of air quality within their jurisdiction by using appropriate measuring instruments, as per Article 5.

The Ambient Air Quality Directive is responsible to set up the annual and hourly limits for all present and hazardous pollutants. The purpose for these restrictions are mainly to protect both human health and prohibit loss of vegetation from occuring. With respect to nitrogen dioxide, the European Commission set an hourly limit value of 200 $\mu g/m^3$ and an annual limit value of 40 $\mu g/m^3$ to protect human health, whereas the same commission set up an hourly limit value of 30 $\mu g/m^3$ for vegetation security. On the other hand, the

European Commission had only set one annual limit value of 5 μg/m^3 for the safeguarding of human health with respect to benzene. Table 2.1 shows a summary of the limit values set by the European Union in Directive 2008/50/EC for each mentioned pollutant.

Limit Values	Time Scale	Nitrogen Dioxide (μg/m^3)	Benzene (μg/m^3)
Human Health	One Hour	200[12]	N/A
	One Calendar Year	40	5
Safeguarding of Vegetation	One Calendar Year	30[13]	N/A

Table 2.1. - Table showing the EU ambient level standards for nitrogen dioxide and benzene (Source: Directive 2008/50/EC).

Directive 2008/50/EC also sets down limitations for the ambient level of ozone, which as discussed before, is an end result of a photochemical reaction involving nitrogen dioxide and VOC's. The same directive also notes down that in order for a long-term air quality progress in terms of ground-level ozone to occur, there needs to be the implementation of good and effective air quality plans. Hence, strategies for the restriction of level of ozone precursor is a necessity. Annex VII of the said Directive adresses human health with respect to ground-level ozone which defines a maximum daily 8-hour mean of 120 μg/m^3, not to be exceeded on more than 25 days per calendar year. This goal had to be achieved by January 2010 and this same objective has to be kept throughout till 2020.

Tropospheric ozone also causes vegetative damage, which as discussed before, is very common within European rural areas. Arsić *et al*. (2011) state that thresholds for the said pollutant concentration are defined with an AOT index. This index is estimated every

[12] According to Directive 2008/50/EC, this value must not be exceeded more than eighteen times a calendar year.

[13] The critical level for vegetation protection in this case is for all oxides of nitrogen and measured in μg/m^3 NO_x (Directive 2008/50/EC).

year and it is the accumulation amount of ground-ozone over the threshold value of 40 parts per billion. It is generally calculated during the day between 8 o'clock in the morning till 8 o'clock at night throughout a specific time period that is relevant for plant growth, being from 1st of May till the 31st of July. Directive 2008/50/EC inidcates that the target limit value of AOT 40 for the protection of vegetation from ground-level ozone is 18,000 $\mu g/m^3$. This needed to be based on a five-year hourly average and achieved by the 1st of January, 2010. Moreover, the same directive sets a long-term objective of 6000 $\mu g/m^3$ for the said pollutant, which objective needs to be attained by 2020.

Apart from European legislation which help to regulate the ambient emissions and concentration of the pollutants under study, there are also international ones. Two of these related multilateral treaties are the following:

- The UN Convention on Long-Range Transboundary Air Pollution (UNLRTAP): this is an international convention which aims that all bound parties shall put their efforts to restrict reduce and avoid long-range transboundary atmospheric pollutants as much as possible (UNECE, 2013); and

- The Marine Pollution Convention (MARPOL 73/78): this international treaty is mainly intended to prevent pollution in the marine environment emitted by operational and accidental causes of ships however, its Annex VI considers the prevention of emissions, particularly nitrogen oxide, via atmospheric deposition from the same vessels (IMO, 2013).

2.5 Public perception on air quality

Public perception has very subjective elements and every individual is free to choose, organise, interpret and apprehend his or her views (Bickerstaff & Walker, 2001). Being a resultant intuitive judgement of any specific concept, one can say that each person's opinion may vary (Slovic *et al.*, 1985). This also applies to air quality and this concept is not perceived through the same angle by every individual (Tokushige *et al*., 2007), so much so Slovic *et al*. (1980) refer to it as "individual psychology".

Perceptions are generally measured by use of social and public opinion questionnaires and surveys. As Howell *et al*. (2003) point out, these questionnaires mainly focus on the localised level of concern on air quality. Public perception in terms of air quality may differ due to individual upbringing and social awareness. When speaking of social awareness, one is not only refering to educative schooling but also, to how much a person maybe influenced by the media.

Previous studies suggest that the majority of the public seem to perceive poor air quality with a number of contributors, namely, motor vehicles and industries (Saksena, 2007). This is mainly due to the fact that the majority of the people seem to associate poor air quality with health risks and diseases (Bianco *et al*., 2008). In fact, Day (2006) states that approximately a third of the global population identifies poor quality of air as being the major contributor to cardiovascular diseases. According to Badland and Duncan (2009), a lot of persons seem to guage air pollution according to the risk incured on one's health. There again, it seems that individuals rank the air quality according to the level of negative results on health occurring in a particular area (Solvic & Peters, 2006), which could not be even related. Therefore, it seems that public perception of human health impacts by poor air quality tend to be influenced more by personal experiences rather than by scientifically-proven sources (Saksena, 2007). One could also note that since public perception about air quality seems to be linked with health problems, the fact that it may also affect vegetation may be disregarded.

According to Bickerstaff & Walker (2001), public perception on air pollution is influenced by a number of factors partly based on real and on virtual truth, which is mainly gathered from second-hand information such as media coverage. The need to improve public perception goes way back in 1992, whereby Chapter 36 of Agenda 21, which deals with sustainable development, addressed the need to adopt training and awareness to give a more clear picture of this situation (UNSD, 1992).

Presently, public perception is giving weight on the state of air quality (Bickerstaff & Walker, 2001). According to Nikolopoulou *et al*. (2011) and De Feo *et al*. (2013), an informed public can be instrumental in leading national governments to adopt measures and create the best available technology to enhance air quality. So it seems, that knowledge and ideas to owners, scientists, policy makers and other people working in the management sector are not the only contributors to determine public policy, since public opinion may help as well.

2.6 An overview of the current position in Malta

2.6.1 Geography of Malta

The island of Malta forms part of the Maltese archipelago, which is located in the middle of the Mediterranean sea and situated approximately 100 km south of Sicily and approximately 290 km north of the African Continent (Busuttil *et al*., 2008; Attard, 2012). With regards to Malta's climate, it is typically Mediterranean with hot, dry summers and wet, mild winters. Furthermore, the most dominant wind in Malta is the *Mistral*, which comes from the North West of the Mediterranean region and blows on an annual mean of approximately 20.7 per cent days (Galdies, 2011).

Malta is the biggest island out of the said archipelago with a total surface area of 246.49 km^2 and a population of approximately 384,912 (NSO, 2012a). The National Statistics Office (2012a) also reported the population density of the island of Malta consists of approximately 1,562 persons per square kilometer which has increased by 45 persons per square kilometer since 2005. The highest population densities in Malta are concentrated around the harbour areas and it decreased as one move outwards (Figure 2.8). This is mainly due to the fact that these area are Malta's central business districts, which as a result lead for more people to live in close proximities. In fact, Figure 2.9 shows that the change in population density within each Maltese locality which shows that there have been more changes within the Northern, Western and Southeastern districts.

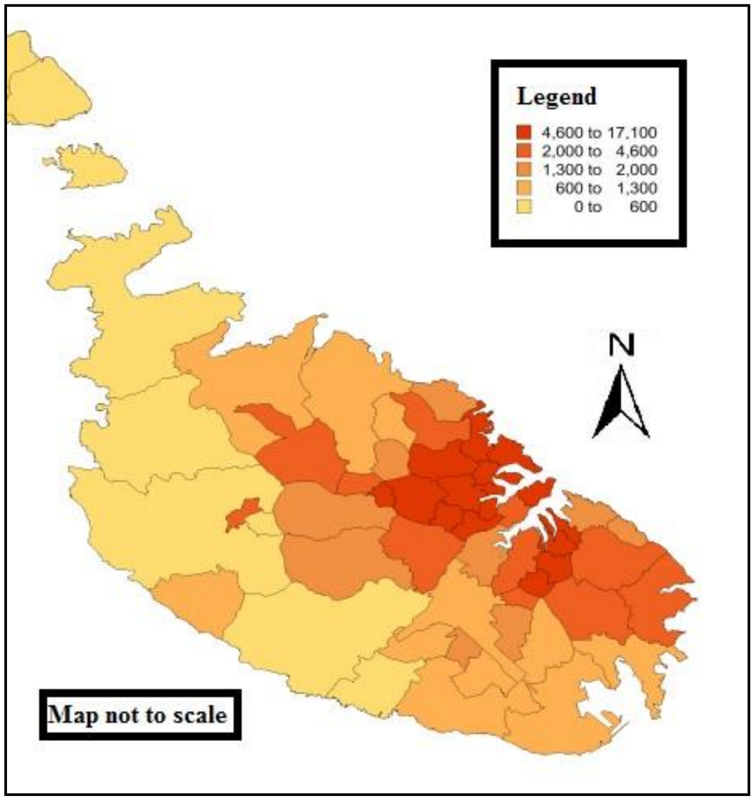

Figure 2.8 - Map showing the population density within each of the Maltese localities, 2011 (Source: NSO, 2012a).

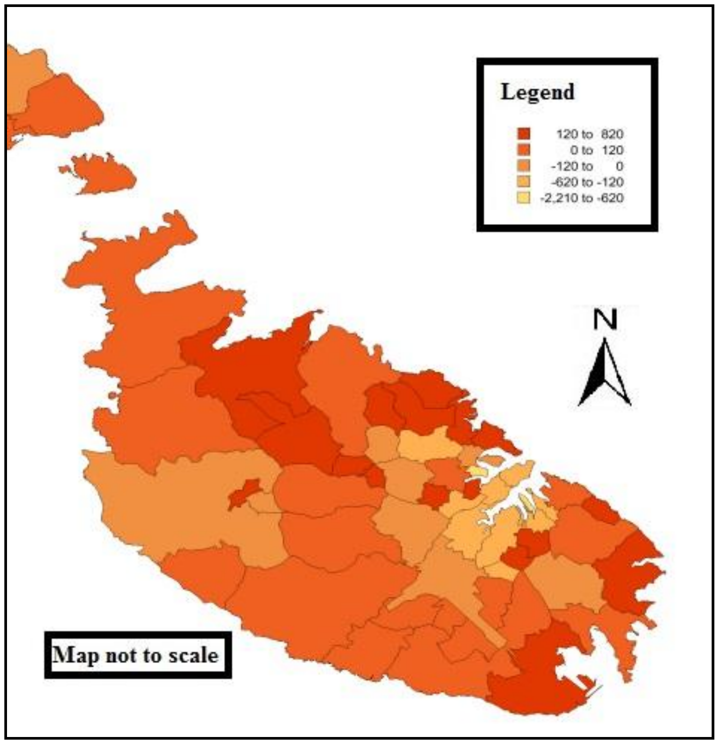

Figure 2.9. - Map showing the change in population density within each Maltese locality, 2005-2011 (Source: NSO, 2012a).

As a result of this, Malta has one of the highest population densities compared with other EU nations and foreign countries and thus, making space very limited (Attard, 2012; NSO, 2012a). Furthermore, this high population density is creating a pressure, such as causing air pollution, since there is more demand for more land, private transport and electrical generation. In addition to this problem, its seems that tourism also contributes to this pressure since most of Malta's economy relies on it[14].

2.6.2 Contributors of air pollution in Malta

Previously, it was discussed that fuel combustion is the primary process which releases hazardous pollutants in the atmosphere. The National Statistics Office (2012b) has identified the top contributors of fuel consumptions, which can be seen on Figure 2.10. The largest contributor of fuel consumption in Malta seem to be the power generation

[14] In fact, Attard (2012) states that nearly one million tourists come to the island every year and which is indirectly exerting more pressures.

with an estimate of 75%, followed by road transportation (19%). Therefore, it seems that these two sectors are the top two sectors which effect the Maltese air quality and this can also be observed in the national air quality plan (MEPA, 2010a).

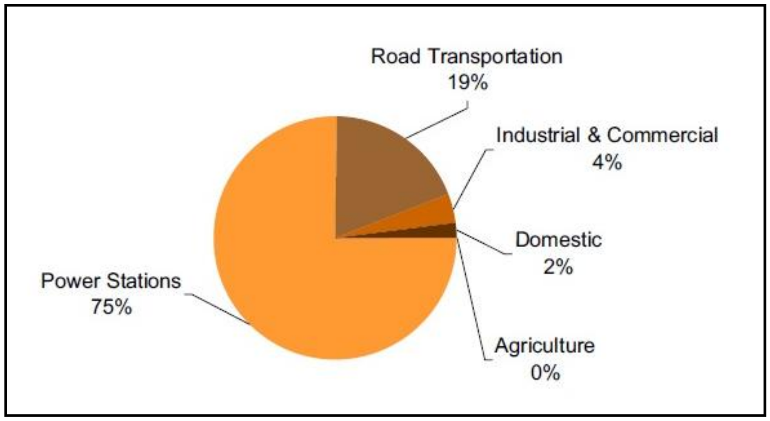

Figure 2.10. - Pie-chart showing the Maltese sectoral consumption of fuels (2011) (Source: NSO, 2012b).

Malta relies completely on fossil fuel burning for its electrical generation, which has been increasing over the past decade (NSO, 2012b) in such a way that it has to meet the demands for all the local sectors (Figure 2.11). The island consists of two interlinked power plants: Marsa & Delimara, both of which are operated by Enemalta Corporation and together they have a total combined nominal installed capacity of approximately 571 MW (Busuttil *et al*., 2008). The plant at Marsa surpassed its economic lifetime with the most recent of its boilers commissioned in 1987 Enemalta (EU Affairs, 2007). According to local media, the four boilers of the Marsa plant have exceeded the 20,000 hour lifetime in the last few years. According to EU regulations, this power station should not be operating. However, this failed to happen since Enemalta claimed that it had an overriding duty to keep a secure supply for the whole nation until the proposed submarine interconnector was functional[15].

[15] This interconnector will be a form permanent source of electricity with the Sicilian regional grid would be completed.

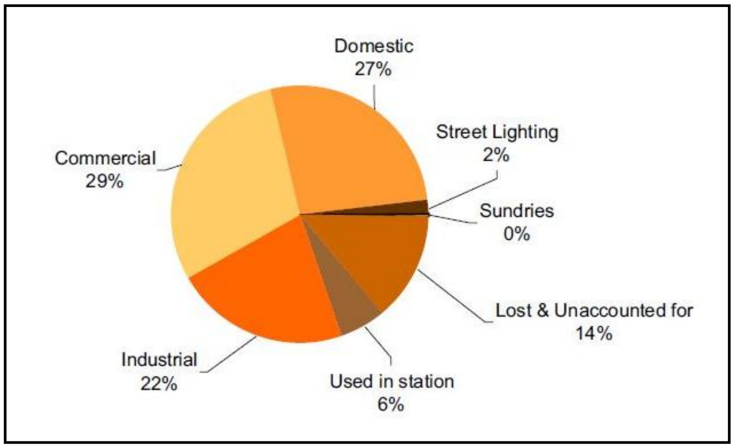

Figure 2.11. - Pie chart showing the sectoral consumption in Malta (2010) (Source: NSO, 2012b).

Attard and Ison (2010) state that Malta has the highest number of private vehicles per capita in Europe. According to the National Statistics Office (2012c), the current number of licenced private vehicles is approximately 239,987, which had been continuously increasing since the late twentieth century (Ellul, 1967; Sutton, 2000). In fact, the Department of Licensing and Testing (2001), as displayed in the Transport Topic Paper (MEPA, 2003), marked a rapid increase of private vehicles throughout the 1990's, in which it determined that the average value of growth of private vehicles was of approximately 7,725 per annum. Given that the number of car ownership has grown rapidly, one can say that besides causing a severe havoc is such a small country, it is one of the major contributor of air pollution since it involves internal combustions to manoeuvre the vehicles (Allegrini & Costabile, 2008).

2.6.3 Measurment of air pollutant levels in Malta

The Malta Environmental & Planning Authority (MEPA) is the responsible competent authority to measure the level of pollutants on the island (MEPA, 2010b). In fact, it measures the monthly averages of the ambient concentration of sulphur dioxide, nitrogen dioxide, ozone and benzene, xylene and toluene by means of diffusion tubes which are distributed in 129 diffusion tubes amongst 40 localities in Malta and Gozo (MEPA, 2013). These tubes are used by MEPA for comparative purposes, i.e. to compare pollutant levels across localities and to identify their hotspots rather than for the purpose of compliance monitoring. Benzene and nitrogen dioxide are two pollutants which are of great concern in Malta since they are emitted during combustion processes and they are considered to have severe and adverse effects.

2.6.4 Benzene in Malta

When one considers the local situation about the total emissions of volatile organic compounds emissions (including benzene), it seems that the latest reading held in 2011 shows that Malta was responsible for 3Gg, as can be seen in Table 2.2 (EEA, 2013b). This value has decreased by 51% since 1990, which was 6Gg. Nevertheless, despite this decrease in volatile organic compounds, Malta's did not contribute for the share in the EU throughout the same time period.

Member State	MVOC (Gg)										Change		Share in EU-27	
	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	1990-2011	2010-2011	1990	2011
Malta	6	8	3	3	4	3	3	3	3	3	-51%	19.4%	0.0%	0.0%

Table 2.2. - Table showing the contribution of Malta to EU NMVOC emissions (Gg) (Source: EEA, 2013b).

According to the latest environmental report (MEPA, 2010b), it seems that the national benzene annual level has fallen significantly, in such a way that between 2006 and 2007, the said level decreased by 10.4% and resulted with a value of approximately 2.4 $\mu g/m^3$. This was mainly due to the fact that more unleaded fuels were used in order to comply with the EU benzene limit value of $5\mu g/m^3$ (EEA, 2010).

2.6.5 Nitrogen dioxide in Malta

Table 2.3 shows the contribution of Malta in the EU with respect to nitrogen oxide emissions between 1990 and 2011. It seems that in 1990, the nitrogen oxide emissions in Malta was 8Gg. This has not changed much due to the fact that in 2011, it also resulted in to 8Gg. Although in Malta there has been a decrease of 4% in nitrogen dioxide emissions between 1990 up to 2011, nevertheless this mentioned decrease only contributed to 0.1% of the EU share.

Member State	NO_x (Gg)										Change		Share in EU-27	
	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	1990-2011	2010-2011	1990	2011
Malta	8	9	8	9	9	9	9	9	8	8	-4%	-3.2%	0.0%	0.1%

Table 2.3. - Table showing the contribution of Malta to EU nitrogen oxide emissions (Gg) (Source: EEA, 2013b).

According to MEPA (2010b), nitrogen dioxide concentrations in Malta increased between 2006 and 2007. The latest national annual reading of the said pollutant has a value of 28.9 μg/m³ (MEPA, 2010b). According to Attard and Ison (2010), a possible explanation for this result could be the significant upsurge of traffic congestion. However, even though nitrogen dioxide concentrations has increased, it has not surpassed its EU annual limit value of 40 μg/m³ (MEPA, 2010b).

2.6.6 Tropospheric ozone in Malta

Malta being located in the Euro-Mediterranean region, like most other European countries can experience very high risks of tropospheric ozone (Sicard *et al*., 2013). Moreover, surface ozone risks in Malta can also be induced due to high temperature and sunlight exposures during the summer months (Millan *et al*., 2000).

The Malta Environment and Planning Authority (2010b) has reported that between 2006 and 2007, the national annual mean ground-ozone levels have declined slightly by one percent, that is to say that from 102.3 μg/m^3 it decreased to 101.3 μg/m^3. Towns and villages situated in rural areas, being distant from harbour districts, appear to have the highest tropospheric ozone concentration. This can be noted in Figure 2.12 displayed below. Such results occur mainly because surface ozone produced in urbanised localities, where nitrogen oxides are freshly emitted, has a higher affinity of getting depleted by titration procedures, as explained previously (EEA, 2012).

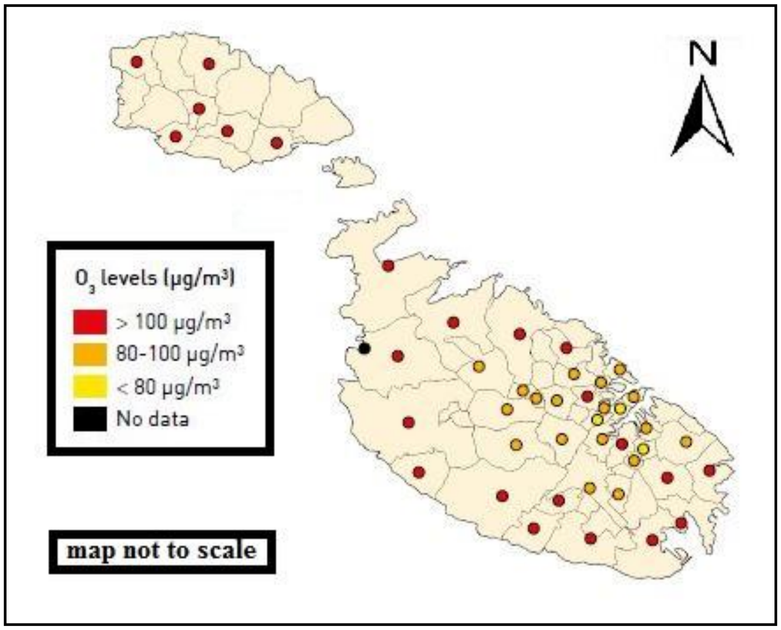

Figure 2.12. - Map of Maltese Islands showing the levels of tropospheric ozone in certain localities (Source: MEPA, 2010b).

On the other hand, the European Environment Agency (2013a) states that the last maximum observed one-hour tropospheric ozone concentration in Malta was of 178 μg/m³. Furthermore, the same agency reported that the concentration of the said pollutant in Malta did not increase throughtout the summer period of 2012. Nevertheless, it resulted that the reading of 2012 was still slightly higher than its preceding summer period of 2011.

2.6.7 Perception on air quality in Malta

The year 2013, being the year dedicated to air by the EC, a survey was held in order to compare public perception regarding air quality in the EU . The results were published in a report: "Flash Euro-barometer 360: Attitudes of European towards air quality", which went into detail how the European citizen perceive the local air quality in their country (EC, 2013). According to this report, a large percentage of respondents from Malta (65%) had highlighted that the local air quality had deteriorated. On the other, 18% of the same respondents stated that it had improved, whereas another 15% stated that they did not perceive any changes in the national air quality.

Moreover, the same Euro-barometer (EC, 2013) shows that the Maltese are very concerned with risks imposed by poor air quality, mainly on human health. Nine out of ten Maltese respondents consider asthma and allergies to be a very serious problem. In contrast, only 77% of Finnish respondents consider this a serious threat. Also, only 34% the Maltese respondents think that acidification is a serious problem. An opposed view is held by Romanians, whereby 88% consider this a major issue. Eutrophication is not regarded lightly and almost all respondents in France, Italy and Portugal are concerned with this issue. In contrast, only 48% of the Maltese respondents consider this as severe problem.

Quite remarkably, all EU respondents seemed to view on-road vehicular emissions with a negative impact on air quality. There again, almost all respondents in Malta think that the quality of air is highly affected by these emissions. Electricity production are also viewed as a threat to air quality by 44% of the respondents in Malta[16]. Only 48% of the Maltese respondents think that air pollution from industries should be seriously addressed. Although, the majority of the respondents of the EU countries all agree that this is not to be disregarded, only respondents in Spain, France, Greece and Portugal have a large percentage of an average of 70% who view this as a great issue which needs to be a priority.

[16] In fact, there have been a lot of controversy regarding this issue since the Marsa Power plant was reported to have been depositing black dust and smoke (Vella, 2011).

The Maltese public think that air pollution problems can be partly tackled by more information on the health and environmental consequences of air pollution. However, Maltese respondents, like three quarters of the respondents in all EU countries, are in favour of the Polluter Pays Principle. However, local respondents were more inclined towards reducing air pollution from energy production rather than changes in their lifestyle that would lead to reduction in emissions.

2.7 Measurement and assessment tools used in the research study

2.7.1 Questionnaires

Questionnaires are important tools to gather useful information about the level of air quality as viewed by the public, as is the case in this research study. These tools have been widely applied in data collection throughout the years since they can provide sufficient information for new innovative ideas (Spruyt & Gozal, 2011). Researchers always try to use a mechanism that will achieve the best result based on the subject. As discussed previously, everyone has different intuitive judgements and thus, questionnaire surveys serve to gauge the view of each respondent (Bargas-Avila *et al*., 2009). According to Webster *et al*. (2011), questionnaires offer a mixture of accuracy and practical application during a population-related assessment, however they can still pose some uncertainties due to the fact that:

- people might interprete information from secondary source which might be false; and
- summarization of the gathered raw data during the analysis can be interpreted differently by the respondents which can therefore, affect the results.

Questionnaire surveys may take three different forms namely

- face-to-face;
- telephone; or
- electronic

For the purpose of this research study, only electronic questionnaires were used. This was mainly done and shared via social media networks. This type of questionnaire has a number of positive advantages, amongst which are as follows:

- feasibility: electronic questionnaires can be constructed by using an online software which is free of charge and furthermore, these questionnaire types do not impose additional travelling costs; and
- respondents' liberty: the respondents may feel more comfortable to reply and moving through the questionnaire survey at their own pace, without the feeling of being 'pushed' (MacKerron & Mourato, 2009).

Nevertheless, electronic surveys can still pose some drawbacks on the perceived data needed to be analysed. The following are a few examples of disadvantages which can be imposed by these types of questionnaires:

- Population Bias: these types of questionnaires are more subjective towards people who are computer-literate, mainly people of the younger generation; and
- Misunderstanding: unlike the other types of surveys, electronic questionnaires cannot provide clarification of the questions and thus, the respondents may not fully understand what they are being asked (MacKerron & Mourato, 2009).

Google Forms® is the online questionnaire software that was chosen in this research study, which specifically designed to construct and conduct such online quizzes and surveys (Zamri Mansor, 2012). This software is very suitable for designing both types of close and open ended questions. Furthermore, Google Forms® can be easily shared through a specialized link online which can be copying and pasted on emails and/or any available social media networks. It operates by using Google Spreadsheets®, which is an online equivalence of Microsoft Excel and thus, once the respondents submit their answers, they are automatically inputted on the same spreadsheet (Herr *et al*., 2011)

2.7.2 Geographical Information Systems (GIS)

Geographical Information Systems (GIS) is a specialised software tool, used in this research study, which: captures, stores, structures, manipulates and displays a series of spatial and geographical data to make further the analysis more visualised and understandable (Burrough, 2001; Mirats Tur *et al*., 2009; Elbir *et al*., 2010). Once, the geo-referenced data is collected, it is inputted in the system as a datasets, i.e. it could either be a point, a line or a polygon depending on the type of entity being recorded (ESRI, 2009). These datasets can be selected, sorted and structured according to the user's criteria. This is done by setting a level of importance to the most needed relevant features. These datasets are classified and represented by means of layers, which are characterized by different levels of detailed information (Harmsworth, 1998). According to Elbir *et al*. (2010) this software is very suitable when handling dynamic environmental models and in fact, GIS has been known to be an appropriate instrument when gauging an monitoring air quality. In fact, Lin *et al*. (2010) states that GIS has been useful to map air pollution in certain places as it encouraged the formulation of air quality action plans. In this research study, the ArcGIS®10 application was used. ESRI, who modelled this program, made sure that it was user friendly.

2.7.3 Kriging

Kriging is an Inverse Weighing Distance (IWD) interpolation technique[17] (Figure 2.13) that is able to predict a best linear unbiased surface based on a particular scattered set of sample points collected from the real world (Robinson *et al*., 2013). Moreover, this advanced geo-statistical interpolating method is capable to provide measures of accuracies, uncertainties and errors of the previously mentioned surface prediction (ESRI, 2003; ESRI, 2011). Kriging is able to assume that the distance/direction between sample points represents a spatial and geographic correlation. This correlation can be applied to explain and describe the variations that occur within the actual surface in the real world (Childs, 2004).

[17] According to ESRI (2003), Inverse Weighing Distance (IWD) interpolation techniques are methods that consider that the weight of a value which reduces as the distance increases from the prediction area.

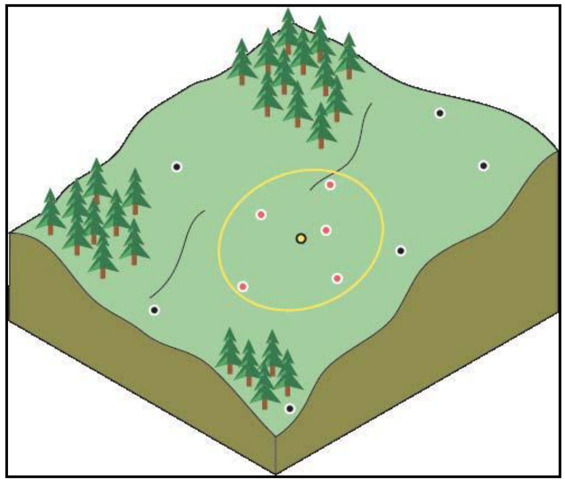

Figure 2.13. - A diagram showing the basis of Inverse Weighing Distance (IWD) interpolation technique (Source: ESRI, 2003).

This geo-statistical test tends to fit a mathematical function to a particular number of points contained by a specified radius to determine the output value for each location (ESRI, 2011). However, there are various kriging approaches, all of which are different with respect to the knowledge and evaluation of the spatial average function (Berke, 2004). ESRI (2003) and Childs (2004) give an account on such approaches, amongst which are ordinary and universal kriging. In this research study, ordinary kriging was applied, which is a widely used geo-statistical approach and will be discussed further on.

2.7.4 Statistical Package for Social Sciences (SPSS)

SPSS is a user-friendly software produced by the International Business Machine Corporation (IBM) which is widely used throughout statistical analyses and was found useful in this research study. This software consists of a number of functions which could be applied to determine any type of predictions, correlations, relationships and tendencies. In fact, IBM (2013) points out that the SPSS software offers a number of statistical tests, amongst which are the following:

- "Analysis of Variances" (ANOVA) test;

- Pearson's *r* correlation co-efficient; and
- Friedman test.

All of these statistical tests will be applied in this research study and will discussed in detail further on.

2.8 Summary

This chapter has reviewed the literature that is relevant in this research study. It seems that anthropogenic activities which involve combustion processes play a crucial role in determining the state of air quality. This is because they contribute significantly in the emissions of atmospheric pollutants, such as nitrogen dioxide and non-methane volatile organic compounds such as benzene. In addition, these two pollutants can react with each other in the presence of high insolation and temperature to produce tropospheric ozone. All of these pollutants are very hazardous since they have the ability to cause adverse health problems and severe vegetative damages.

Results regarding the state of air quality in Europe (including Malta) show that it has relatively improved over the past two decades. This can be shown by the decrease in the atmospheric emissions of certain atmospheric pollutants. This could have occurred due to the implementation and enforcement of EU and international legislations. These help to regulate the state of air quality by setting limitations and restrictions on the emissions of such air pollutants.

Nevertheless, not every individual perceive the state of air quality in the same way, as is the case in Malta. In fact, a large number of Maltese citizens think that the national quality of air is very poor and it has been deteriorating due to increase in vehicular emissions which as a result, cause health problems. The reasons for these perceptions are various, however these opinions can be widely affected by non-scientific secondary sources.

Specific instruments were used in order to observe the relationship between the data perceived by the Maltese citizens and the actual measured reading of air pollutants in the local atmosphere. Questionnaires can be conducted to obtain perceived information regarding the state of air quality around the nation. This can later be integrated with actual data of atmospheric pollutants obtained from diffusion tubes situated in various localities by using appropriate statistical tests. These data can help to predict the spatial distribution trends of the air pollutants by the use of GIS and kriging geo-statistical tests.

3 Methodology

3.1 Introduction

This chapter will describe the methodological procedures which were used in this research study. The processes taken for the interpolation of the data collected from the diffusion tubes shall be initially presented. These data consist of the annual averages of benzene and nitrogen dioxide which were monitored by the national competent authority at various sites from 2005 till 2012, in a manner that shall be addressed later on in this chapter. These same data were inputted on GIS to analyse the spatial distribution and trends of these two pollutants. Eventually, this chapter shall continue to focus on the procedures taken for the analysis of the data on public perception. These data were collected from a sample of respondents who participated by means of questionnaires throughout the time period of this research study. Furthermore, this chapter shall discuss the statistical tests used in this study and to what context they were applied.

3.2 Analysis of the diffusion tube data

3.2.1 Selection of air pollutions

The previous chapter gave a brief overview on the various types of atmospheric gaseous pollutants. However, only benzene and nitrogen dioxide were opted for as the indicators of air pollution on the island of Malta. This occurred due to the fact that both pollutants are known to be very hazardous nationwide since they contribute significantly to the following:

- the deterioration of the state of air quality;
- the production of chronic and acute health issues; and
- the formation of serious threats on human welfare;
- the creation of tropospheric ozone by means of light and temperature driven reactions, which mainly pose severe impacts on vegetation.

Sulphur dioxide was excluded since a recent study showed that its national levels have decreased over the past decade (Desira, 2012). As a result of this, the same study discovered that the annual levels of sulphur dioxide were only relatively higher within the localised area surrounding the Marsa power station, whereas the annual readings of the same pollutant in the inland areas resulted to be negligible. On the other hand, tropospheric ozone was not included in this research study since it is a secondary pollutant produced by light-induced chemical reaction involving nitrogen dioxide and VOC's, as explained earlier on. Thus, it is not emitted directly by anthropogenic sources.

3.2.2 Data collection and inputting

Two Microsoft Excel spreadsheets containing the reading levels of benzene and nitrogen dioxide were collected from MEPA records. These data consisted of average monthly readings of both air pollutants measured from March 2004 till May 2013. Both spreadsheets also contained the locality, the diffusion tubes and the co-ordinates of where the recorded pollutant levels were taken from. Eventually, average annual readings for each pollutant were estimated and inputted into two other data spreadsheets. These mentioned averages were calculated by using the average function which is available in Microsoft Excel. It is important to point out that the 2004 and 2013 monthly readings for both pollutant levels were eliminated. This is due to the fact that not all the twelve months of year were available for the calculation of the average annual readings. Moreover, before the annual averages for each pollutants were estimated, a data cleaning procedure had to be done due to some missing values.

3.2.3 Data cleaning

Data cleaning is a necessary, preliminary procedure in which its main aim is to enhance the data quality in order to be reliable for the analysis (Jagannathan & Wright; 2008), According to Han and Kamber (2006), data extracted from the real world tend to be either incomplete, noisy and/or inconsistent. Thus, this procedure tries to fill in data if they are missing, smooth them out the data if they are noisy and correct them if they are inconsistent.

In the case of this research study, the data cleaning technique needed to fill in the missing values. This proves to be a very common issue in large data sets. This might occur due to numerous systemic reasons, such as temporary damage in the diffusion tubes, loss of data, sensor failure and human-related errors (Muteki *et al*., 2005). Missing data are important to be handled well as they can lead inaccurate results (Kwak & Kim, 2012). Hence, data cleaning has the ability to substitute absent values with others by using a number of techniques. Han and Kamber (2006) advocate a number of techniques, amongst which are the following:

- ignoring the tuple[18];
- manual filling of missing values;
- using global constants;
- using the attribute mean;
- using the attribute mean for all samples belonging to the same class as the given tuple;
- and using the most probable value.

In this case, the procedure chosen was "the use of attribute mean for all samples belonging to the same class as given tuple". The samples were assumed to be the number of diffusion tubes in a particular locality and the class was assumed to be the time period in that same particular locality.

3.2.4 Importation of data on ArcGIS

Once the data cleaning procedure was ready, the two Microsoft Excel files containing the annual reading of both pollutants under study were converted into a comma-separated value (CSV) file, which can be seen on the tables in Appendices H and I. This was

[18] A tuple is an ordered list of records/elements which is generally stored in an attribute table (Han and Kamber, 2006).

mainly due to the fact that ArcGIS allows an easy facility of data importation in this format. Moreover, in order for this importation to happen, the files of data must be furnished with some information of the location (ESRI, 2013) and in case, the co-ordinates of the diffusion tubes were refered to. These co-ordinates consisted of the eastings (*x*-axis) and northings (*y*-axis) for each respective diffusion tube. The co-ordinates present in the two spreadsheets provided by MEPA were in a WGS84 format. However, these co-ordinates had to be converted into a Universal Transverse Mercator (UTM) co-ordinate system[19] in order to be facilitated better by ArcGIS®. This conversion was done by means of the "Projection and Transformation" tool found in the "Data Management Toolbox" of the said GIS software.

On GIS software, shapefiles were created for both the data of two air pollutants. These were displayed in the form of points which were based on the previously mentioned co-ordinates of the diffusion tubes. A base map showing the island of Malta was imported on ArcGIS, which was displayed behind the layers of the said shapefiles. This was done in order to have a clear visualisation of the spatial distribution of the diffusion tubes along the island.

3.2.5 Application of kriging

Kriging was applied for every annual average reading of each atmospheric pollutant. This was done by selecting the kriging spatial analyst tool, which is already available in the ArcGIS's Toolbox. The kriging method used was ordinary kriging, which is widely used when there are no constant trends over a particular area under study (Child, 2004). Once this method was applied, many raster layers were created and overlayed on the base map of Malta. Each raster layer produced represents the projected spatial distribution trends of each pollutant throughout a specific year. Eventually, the produced maps were exported into a JPEG format to be further analysed further on.

[19]Malta is located in the Northen hemisphere of zone 33 of the said UTM co-ordinate system.

It is important to point out that the application of kriging or any other type of IDW interpolation techniques pose a serious drawback (DCG, 2013). This is due to the fact that it only considers all the samples which fall within the rectangular area formed by the most-furthest points. This actually happened throughout the interpolation of the diffusion tube data in this research study. As result of this, certain parts of Maltese localities, namley Birzebbuga, Marsaskala and Zurrieq had to be excluded since they do not fall under the rectangular area of kriging.

3.3 Data analysis of the perceived data

3.3.1 Construction of questionnaire

A questionnaire was constructed in order to collect information related to public perception on air quality on the island of Malta and in its localities (Appendix A). It was made in such a way that it would be user friendly to the respondents. The aim of this questionnaire was to gather as much data as possible is a short time. The questions were layed down in the following manner:

- close-ended questions for gauging and selecting purposes; and
- open-ended so that respondents can express their opinion.

Furthermore, it is important to point out that both English and Maltese languages were used in the questionnaires in order to facilitate a better communication with the respondents.

Special online questionnaires were used in an online questionnaire software called Google Forms®. The reason why electronic questionnaires were chosen is because, compared to face-to-face and telephone surveys, these type of questionnaires are cheap, less time consuming and more ideal for a research study with a very short time frame. Another reason why electronic surveys were chosen is because Malta has a percentage of people using computers which is quite high. In fact, the National Statistics Office (2012d) had recorded that approximately 80% out of a total population aged between 16 and 74 had access to a computer at home in 2011. Nevertheless, electronic surveys still pose some limitations. One could say that through this system, the younger generation may be more of a target since it is more computer-literate.

A detailed overview on the construction of each question in the electronic shall be described as follows:

- Cover letter

A cover letter was inserted prior to the questionnaire in order to abide by the Institutional Review Board (IRB), which is an organisation which ensures that no risks are imposed on individuals throughout a human-subject-related research. This cover letter consisted of a small introduction stating the purpose of this study and that all information will remain private/ confidential and discarded once the research study is finished. Furthermore, to be in line to the IRB regulations, in the cover letter there was a caution that such questionnaires should not be answered by: minors, prisoners, pregnant women, foetuses, cognitively impaired persons or other protected and/or other potentially vulnerable population.

- Current level of air quality

In the first question, the respondents were asked to gauge the level of air quality on the island of Malta, in their home locality and other particular localities. These localities were chosen specifically to ensure that they come from various parts of Malta so that eventually they could be compared. The localities selected are the following:

  - Birkirkara: this town was chosen as it is the largest populated nationwide;
  - Mellieha: this locality was chosen since it is situated on the far North of Malta;
  - Marsa: this was chosen since it is a locality which is fully industrialised, consists one of major arterial roads of Malta and is home to one of the power stations on the island;

- Mosta: this was selected since it is a locality which situated approximately in the middle of Malta;
- Rabat: this locality was chosen since it is positioned on the high elevated areas of Malta surrounded by rural areas;
- Marsaxlokk: this locality was chosen since it situated on the South-eastern side of Malta and is home to the other power station;
- Paola: this town was opted for due to its position in the Southern harbour area;
- Sliema: this locality was chosen since it is located on the Northern harbour area; and
- Valletta: this was chosen since it is a locality in which it experiences a large number of commuters almost every day of the week.

The mentioned gauge is based on a scale from one to ten, where one represents poor air quality and ten represents good air quality. Furthermore, respondents were also given the option not to use the gauge, if they had no knowledge about the present state of air quality.

- Change in level of air quality

Respondents were also asked to gauge the change in level of air quality within the same places mentioned previously over the past three years. The time frame of change was chosen to be short since otherwise, it would be too far back for the respondents to remember and automatically, it would exclude people who are currently under a certain age. With regards to scale, it is very similar to the previous one. However, in this case one represents a shifts towards poor air quality and ten represent a shift towards good air quality. Also, respondents had the option not to gauge if they felt they did not know change in air quality.

- Source of information

In the surveys, the respondents were asked about the source of information about the air quality within the previously mentioned 11 places. They asked to select from a selection of four answers, which are:

- Personal observation: which includes examination of the air quality from the respondents' personal experience;
- Media: which includes the influence made by newspapers, internet and news, programs and commercials broadcasted by television and radios;
- Education: such information gained by learning and researching; and
- Others: which can include any other source of information except for the previously mentioned three.

- Contributors and sources of air pollution

The respondents were asked to give an account of three specific sources of air pollution which they think are very crucial in their home localities. This question was left open-ended in such a way to see what the respondents had to answer. In fact, once the questionnaires were conducted and finished, the respondents had come up with a wide variety of air pollution contributors. Some of the answers were very similar to each other and therefore, they were classified into groups according to their similarities. Table 3.1 shows a summary of categorisation of the perceived sources which negatively affect air quality.

Contributor of Air Pollution	**Including**
On-road vehicles	Cars, transport, trucks, public transport, light weight vehicles, heavy weight vehicles and heavy traffic.
Construction works & quarries	Airborne particles from quarries, building and road constructions
Power stations	
Urbanisation	Domestic & Commercial buildings, use of household appliances & chemicals, over-population, use of sprays and

	removal of vegetation.
Industries	Factories, chemical-use industries and industrial estates.
Off-road vehicles	Airplanes, ships and boats.
Waste & sewage treatment	
Agricultural practices	Use of pesticides, insecticides and fertilizers.
Lack of green areas	
Incineration	Hospital incineration and burning.
Natural resources	Meteorological conditions.
Others	Use of BBQ's, vandalism, fireworks and cigarette smoking.
Blank and/or invalid replies	

Table 3.1. - Table showing the classification of the perceived air pollution contributors (Source: Author, 2013).

- Health impacts of air pollution

The respondents here were asked to point out the potential health impacts of air pollution in their localities. This question was also constructed in an open-ended manner to give liberty to the respondents to express their views. Table 3.2 shows a summary of the perceived health impacts according to the Maltese respondents. The health impacts in this case were also classified to facilitate the nature of the health problem.

Health impacts of air pollution	**Including**
Asthma & other respiratory problems	Asthma, breathing problems, bronchitis, chest infections, coughing, wheezing, COPD, chest infection, pneumonia, emphysema, colds and sneezing.
Cancer	General cancer, pulmonary cancer and leukemia.
Allergies & hay fever	
Physiological & physical health problems	Tiredness, fever, dehydration, fatigue, nausea, fainting and strain.
Cardiovascular problems	
Body irritation	Skin irritation, eye irritation and eczema.
Headaches	Migraines and sinus attacks.
Mental & psychological health problems	Stress and depression.
Immunity problems	Infections
Child health problems & birth defects	
Others	Gastrointestinal, renal, hepatic, neurological, hematological and reproductive system problems
Blank and/or invalid replies	

Table 3.2. - Table showing the classification of the perceived health impacts of air pollution (Source: Author, 2013).

- Demographics

Respondents were also asked to give some details regarding their demographics. These mainly included the following:

  - age;
  - gender;
  - home locality;
  - occupation; and
  - level of education.

Demographics proved helpful as one could link certain answers and compare the different opinioins.

- Additional comments

At the end of the questionnaire, repsondents were free to provide any further information. In fact, some of the respondents continued elaborating and discussing on the state of air quality. These respondents also highlighted on other possible impacts (eg. vegetation) rather than those affecting human health and some basic measures to overcome this issue.

3.3.2 Distribution of the questionnaire

The finalised electronic survey was shared via a social media network throughout the summer months, namely via Facebook, being the most popular social media network nationwide. This mentioned social media network is an online connection community whereby, it is used by different people. Hence, sharing a questionnaire via Facebook groups is ideal since it can target different people in terms of age, gender, home locality, occupation and level of education. Furthermore, it seems that on Facebook, people are willing to give information about themselves and people seem to be more willing to answer questionnaires because they can do so at their leisure.

It is important to point out that the distribution of questionnaire via Facebook took place after the approval from the IRB. This had been approved after the IRB committee met up and saw the protocol which stated the purpose and procedures taken for this study to occur. Furthermore, it was ensured that the questionnaire were posted online at various times of the day in order to get a wide variety of people. Once the respondents answered the questionnaire, their answers were inputted in a password-protected spreadsheet automatically by the said online questionnaire software. The distribution of the surveys came to an end once a minimum of 400 replies were reached. At this point, the spreadsheet containing the replies of the respondents was downloaded and the data were analysed.

3.4 Statistical tests

3.4.1 One-way "Analysis of Variance" (ANOVA) test

The one-way analysis of variance, also known as the one-way ANOVA test, is generally used to find out whether there are any significant differences between the averages of two or more independent variables (Laerd Statistics, 2013). One-way ANOVA test is used to compare the mean benzene and nitrogen dioxide levels monitored by the diffusion tubes between the different years and between different localities. Therefore, the null hypothesis specifies that the mean benzene and nitrogen dioxide levels differs marginally between the different years and the different localities and is accepted if the p-value exceeds the level of significance. On the other hand, the alternative hypothesis specifies that the mean benzene and nitrogen dioxide levels differs significantly between the different years and the different localities and is accepted if the p-value is less than criterion.

3.4.2 Pearson's (r) correlation

This statistical test identifies whether there is a relationship (i.e. correlation) between two specific variables (Weir, 2013). This types of correlation can either be:

- positive, in which the variables tend to increase;
- negative, wherby the variables tend to decrease; or
- null, whereby the variables do not increase or decrease.

This can shown more clearly in the the scatter plots in Figure 3.1.

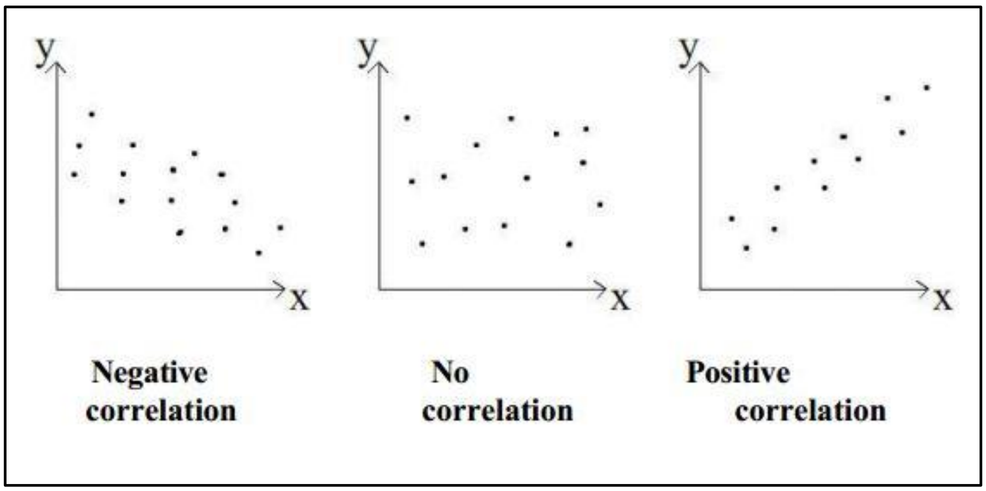

Figure 3.1. - Three scatter plots, each representing a positive, negative or no correlation between specific variables (Source: Weir, 2013).

In order to test for the strength of the correlation, the Pearson (r) correlation co-efficient can be used (Weir, 2013)[20]. This can be done by using the following equation:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where:

- x and y are the variables under study; and

[20] This is only applicable for a linear relationship (correlation) between the variables.

- n is the total number of variables.

The results obtained from this correlation co-efficient can be at a range from -1 to 1 $(-1 \le r \le 1)$. Therefore, if the obtained results will be:

- -1 or closer to -1, there is a strong positive relationship;
- 0 or closer to 0, there is no relationship; and
- 1 or closer to 1, there is a strong negative relationship.

Pearson's (r) correlation co-efficient was applied to correlate the levels of benzene and nitrogen dioxide. Therefore, the null hypothesis specifies that there is no relationship between benzene and nitrogen dioxide levels and is accepted if the p-value exceeds the 0.05 level of significance. The alterative hypothesis, on the other hand, specifies that there is a significant relationship between the two levels of benzene and nitrogen dioxide and is accepted if the p-value is less than 0.05 criterion.

Moreover, this statistical test was also applied to correlate both the gauge levels assessing the current and the change in state of air quality provided by the respondents with the actual levels of benzene and nitrogen dioxide measured by the diffusion years across the years. Thus, a null hypothesis was set up which is there is no relationship between the perceived questionnaire data on both current and change in state of air quality and the diffusion tube readings of both pollutants monitored at the diffusion tubes. This will be accepted if the p-value exceeds the 0.05 level of significance. In contrast, the alternative hypothesis specifies that there is a significant relationship between the questionnaire and diffusion tube data and is accepted if the p-value is less than the 0.05 criterion.

3.4.3 Friedman Test

The Friedman test is very similar to the ANOVA statistical test. However, the former is a useful non-parametric alternative of the later, set up by Milton Friedman, which is used to test for dissimilarities amongst groups when the dependent variable being measured is ordinal (Laerd Statisitcs, 2013). The Friedman test will be applied for the mean gauge levels provided by the respondents for both the current and the change in level of air quality in Malta and some of its localities. The range of the gauge level is between 1 to 10, where previously it was mentioned that:

- in the case of the current level of air quality, 1 represents very poor air quality and 10 represents good air quality; and
- in the case of the change in level of air quality, 1 represents a shift towards poor air quality and 10 represents a great improvement in the level of air quality.

The null hypothesis specifies that the mean gauge level for both the current and the change in level of air quality vary marginally between the localities (including Malta) and are accepted if the p-values exceed the 0.05 level of significance. The alternative hypothesis specifies that the mean gauge level provided for both current and change in level of air quality vary significantly between the localities (including Malta) and are accepted if their p-values are less than 0.05 criterions.

4 Data Analysis

4.1 Introduction

The analysis of all gathered results from the diffusion tubes and questionnaire data shall be addressed in this chapter. For easier reference, three specific sections will be tackled as follows:

- The actual data shall be treated in the initial section. Readings of benzene and nitrogen dioxide levels which were collected from various localities at different time periods shall be observed. This would prove useful for the analysis and discussion of the trend of these air pollutants within the island of Malta over the previous years.
- In the second section, the analysis and discussion in terms of the data related with public perception shall be undertaken. These data shall include the observations made from the conducted online questionnaire surveys. These data would be related to the respondents' opinion on the level of air quality, how it is affected and the resultant health impacts.
- Finally, the third section shall focus on the relationship between the actual and perceived data with an examination on the outcome.

4.2 Analysis of the actual diffusion tube data

4.2.1 Location of diffusion tubes

In Malta and Gozo, there are 129 diffusion tubes widely distributed in various localities. For the sake of this research study, only the air pollutants data recorded from the diffusion tubes situated on the island of Malta are going to be considered[21]. These diffusion tubes amount to a total of 113, as indicated in red on the Figure 4.1.

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[21] The reason why Gozo was not considered in this research study was mainly due to its minimum recorded readings of benzene and nitrogen dioxide level readings.

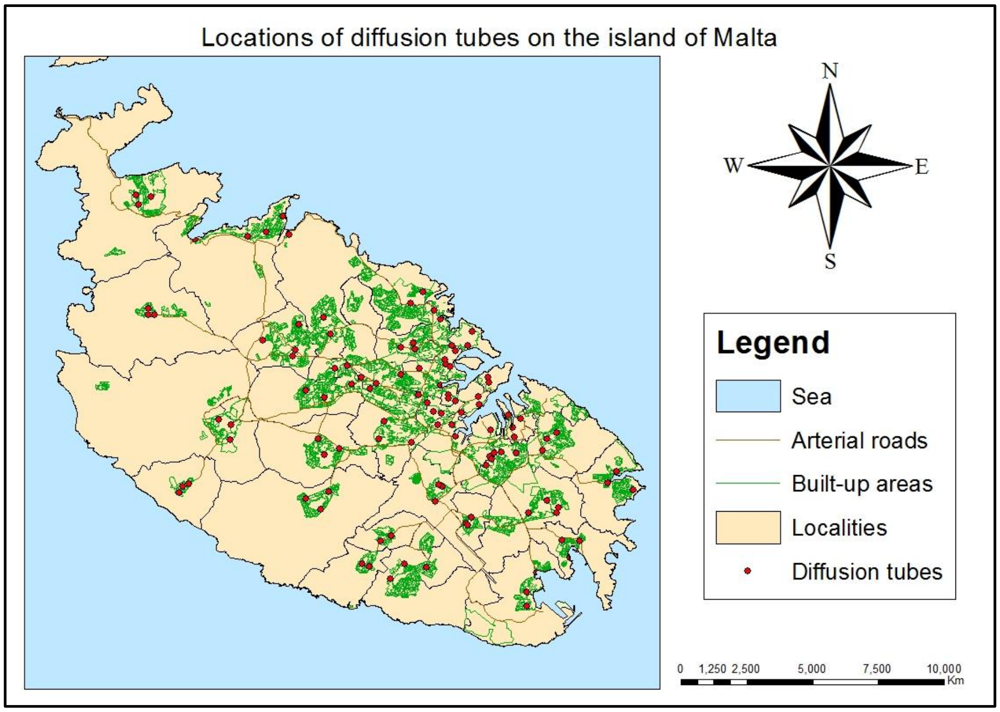

Figure 4.1. - Map showing the locations of air pollutants diffusion tubes on the island of Malta (Source: Author, 2013).

As one can observe from Figure 4.1, the majority of the diffusion tubes are clustered around the central part of Malta. The main reason of this clustering is due to the fact that the localities situated within these areas are widely developed (NSO,2012a; Pace, 2012). Hence, these areas are more prone to air pollution due to circulating traffic, extensive urbanisation, rapid industrialisation and a lot of other anthropogenic activities.

4.2.2 Benzene levels

Figure 4.2 displays the latest annual mean levels of benzene around Malta. At first glance, one can notice that the benzene levels are relatively higher around the previously mentioned urbanised harbour areas and tend to decrease in the outer areas. This high result in the harbour regions is mainly due to the large traffic flow which continuously circulates the same area with the result that benzene-containing petrol exhaust is released in the atmosphere. The inland areas experience less traffic and thus, benzene levels are very low. This means that benzene can be considered as an indicator of traffic intensity.

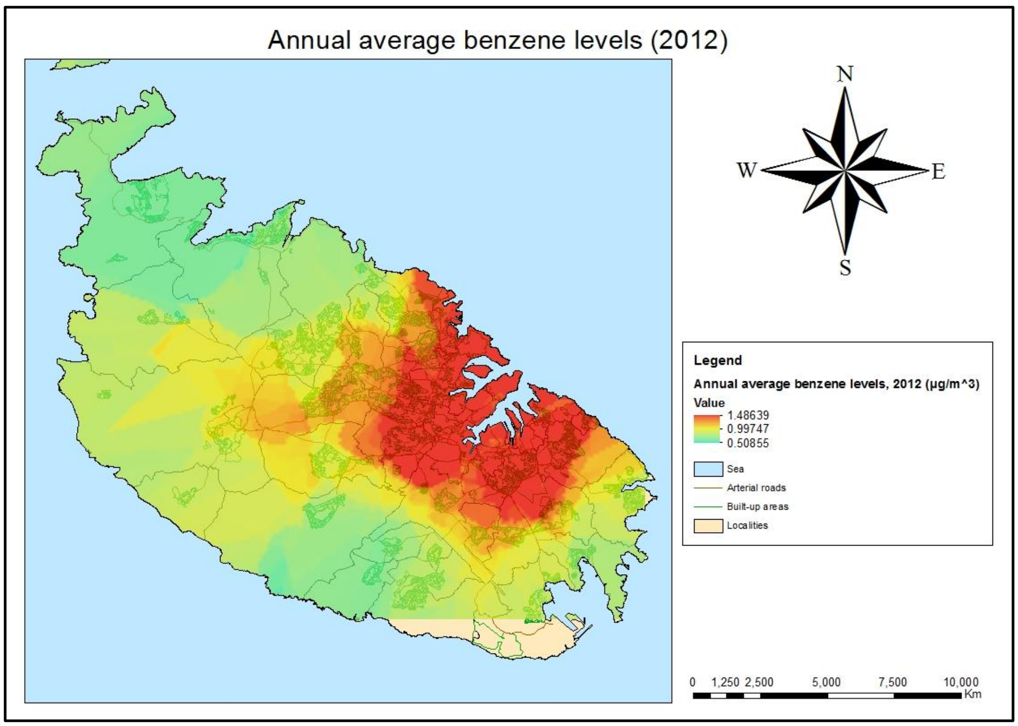

Figure 4.2. - Map showing the recent 2012 annual average benzene levels, μg/m^3 (Source: Author, 2013).

Table 4.1 and Table 4.2 were formed after the application the one way ANOVA statistical test. It can be observed that the mean benzene level varies across different localities which contain diffusion tubes. However, this variation in the mean benzene levels is significant due to the fact that the p-value (≈ 0), is less than 0.05 level of significance. Furthermore, Figure 4.3 displays all the benzene level means of the mentioned localities. It can be observed that the places such as Fgura, Hamrun and places which are in their vicinities have relatively higher means of the said pollutant levels compared with other places, such as Mgarr and Qrendi which are situated far away from the harbour areas and in a rural settings. In fact, if one had to notice, most of the obtained results in Figure 4.3 seem to correspond with the benzene levels distribution displayed in Figure 4.2.

Locality	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Attard	2.212	0.896	0.239	1.695	2.729	0.61	3.50
B' Bugia	1.915	0.841	0.184	1.532	2.298	0.42	3.63
B' Kara	2.731	1.207	0.228	2.263	3.199	0.79	5.58
Bugibba	1.753	0.728	0.123	1.503	2.004	0.41	3.00
Balzan	2.439	0.849	0.227	1.949	2.929	0.97	3.48
Cospicua	2.849	1.266	0.276	2.273	3.425	0.74	4.78
Senglea	2.573	1.129	0.427	1.529	3.617	0.91	3.64
Dingli	1.585	0.765	0.167	1.236	1.933	0.38	2.86
Floriana	3.531	2.274	0.608	2.218	4.845	0.68	6.85
Gudja	2.036	0.774	0.169	1.684	2.388	0.79	3.38
Gzira	2.787	0.949	0.207	2.355	3.219	1.10	4.33
Hamrun	3.646	1.237	0.270	3.083	4.209	1.46	5.30
Kordin	1.073	0.233	0.088	0.857	1.289	0.66	1.34
Lija	2.216	0.948	0.253	1.669	2.764	0.67	3.59
Luqa	2.348	0.859	0.188	1.956	2.739	0.75	3.57
Mgarr	1.505	0.629	0.137	1.219	1.792	0.51	2.47
Mellieha	1.608	0.720	0.157	1.280	1.935	0.41	2.94
Mqabba	1.669	0.769	0.205	1.226	2.113	0.54	2.57
Marsa	2.181	0.815	0.154	1.865	2.497	0.97	3.39
Msida	2.518	1.056	0.231	2.037	2.999	0.61	4.34
M' Skala	2.007	1.107	0.241	1.503	2.511	0.36	4.03
Mosta	2.408	1.300	0.284	1.816	3.000	0.56	5.02

M' Xlokk	1.790	0.903	0.197	1.380	2.201	0.40	3.34
Naxxar	1.641	0.739	0.161	1.304	1.977	0.39	2.75
Paola	2.135	0.950	0.254	1.586	2.684	0.73	3.28
Tarxien	2.710	0.991	0.265	2.138	3.282	0.99	3.89
Fgura	3.729	1.148	0.307	3.067	4.392	1.68	4.78
Pieta	2.539	0.931	0.203	2.115	2.962	0.88	3.53
Qrendi	1.370	0.663	0.177	0.987	1.753	0.36	2.41
Qormi	2.290	0.952	0.208	1.856	2.723	0.70	3.89
Rabat	2.297	1.135	0.248	1.780	2.814	0.68	4.46
Siggiewi	1.553	0.618	0.135	1.272	1.835	0.47	2.51
S. Gwann	2.779	1.309	0.286	2.183	3.374	0.71	5.16
Sliema	3.165	1.189	0.260	2.624	3.707	1.22	5.20
Swieqi	1.938	1.056	0.179	1.575	2.301	0.39	4.54
Valletta	1.941	0.813	0.217	1.471	2.410	0.76	3.40
Zebbug	2.203	0.913	0.199	1.787	2.619	0.72	3.87
Zabbar	2.618	1.081	0.236	2.126	3.110	0.85	4.56
Zurrieq	1.799	0.700	0.187	1.395	2.202	0.53	2.65
Safi	1.517	0.731	0.276	.841	2.193	0.48	2.42
Zejtun	2.035	0.796	0.150	1.726	2.344	0.49	3.08

Table 4.1. - Table showing the descriptives of benzene levels (μg/m^3) with respects to localities containing the diffusion tubes (Source: Author, 2013).

	Sum of Squares	**df**	**Mean Square**	**F**	**P-value**
Between Groups	252.637	40	6.316	6.391	0.000
Within Groups	741.207	750	0.988		
Total	993.844	790			

Table 4.2. - Table showing the ANOVA test results for benzene levels (μg/m^3) with respects to localities containing the diffusion tubes (Source: Author, 2013).

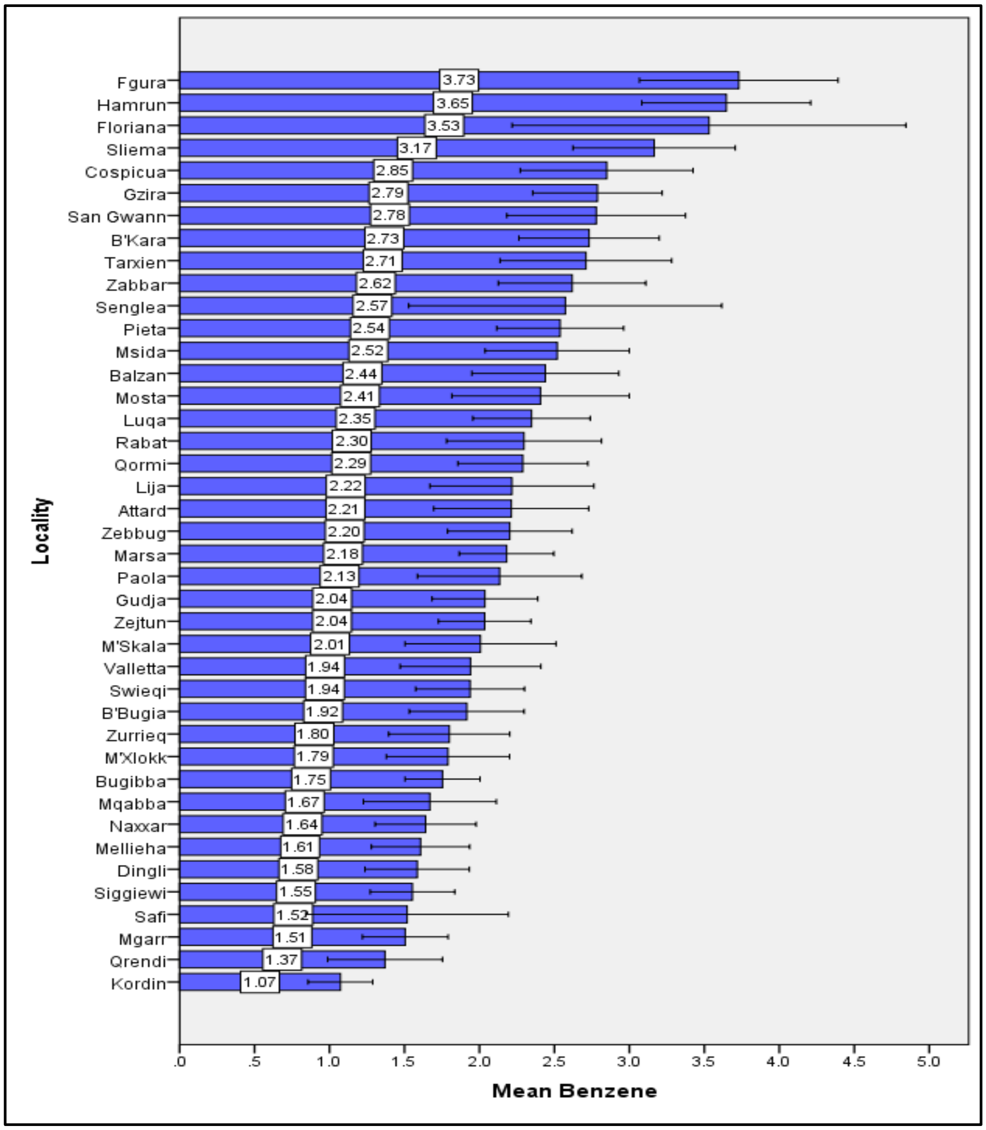

Figure 4.3. - Bar graph showing the benzene means (μg/m^3) in Maltese localities containing the diffusion tubes (Source: Author, 2013).

Figure 4.4 displays the spatial distribution of annual benzene concentration between 2005 and 2012. These maps are based on the trends of benzene levels which were inputted in the attribute table on GIS (Appendix B). It can be observed that in this case, the spatial distribution of benzene levels did not vary that much. That is to say that the regions around Valletta experienced high levels of benzene when compared with the rest of the island.

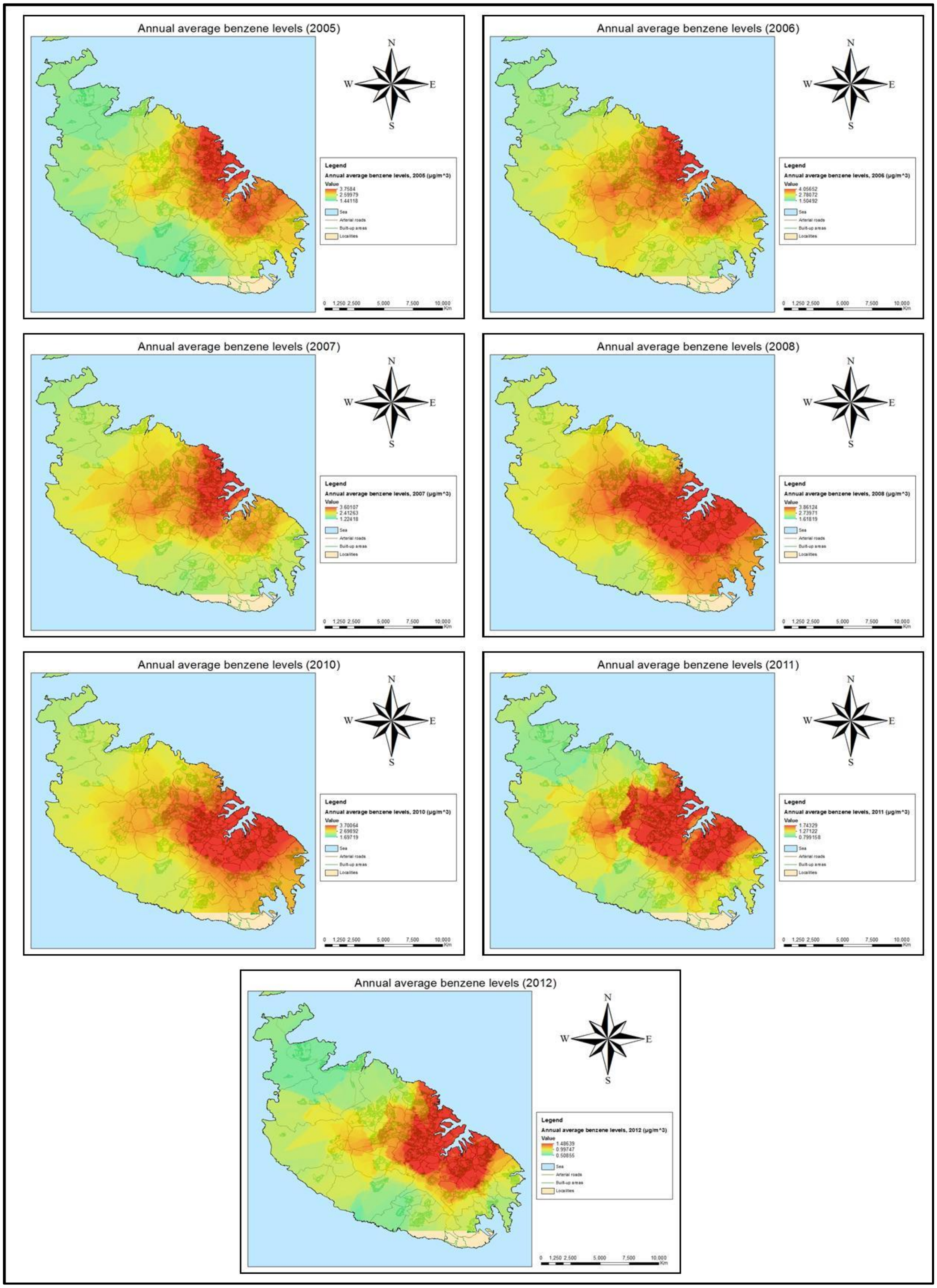

Figure 4.4. - Maps showing the change in annual average benzene levels ($\mu g/m^3$) between 2005 and 2012 (Source: Author, 2013).

The mean annual levels of benzene monitored by each diffusion tube between 2005 and 2012 can be observed in Table 4.3 and Figure 4.5. It can be observed that the average concentration of benzene levels varies marginally from 2005 to 2010 but decreases abruptly in 2011 and 2012. The reduction in the mean benzene levels is significant since the p-value (≈ 0), which was estimated from the one-way ANOVA test and tabulated in Table 4.4, is less than the 0.05 level of significance. The significant decrease of benzene levels in the last two years might have been due to the omission of vehicular lead-containing petrol in the recent years. Furthermore, this significant decline in benzene concentrations throughout the past few years could also have been due to the adaptation and enforcement of the 2008 EU Ambient Air Quality Directive.

Year	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
				Lower Bound	**Upper Bound**		
2005	2.573	1.012	0.095	2.384	2.761	0.99	6.85
2006	2.815	1.022	0.096	2.625	3.006	1.02	6.70
2007	2.359	0.911	0.086	2.189	2.528	1.09	6.50
2008	2.944	0.890	0.084	2.778	3.110	1.34	6.06
2009[22]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2010	2.848	0.751	0.071	2.708	2.988	1.17	5.58
2011	1.222	0.514	0.048	1.126	1.317	0.50	3.74
2012	0.923	0.475	0.045	0.835	1.012	0.36	2.63

Table 4.3. - Table showing the descriptives of benzene levels ($\mu g/m^3$) with respect to time (Source: Author, 2013).

	Sum of Squares	**df**	**Mean Square**	**F**	**P-value**
Between Groups	462.401	6	77.067	113.691	0.000
Within Groups	531.443	784	.678		
Total	993.844	790			

Table 4.4. - Table showing the ANOVA test results for benzene levels ($\mu g/m^3$) with respects to time (Source: Author, 2013).

[22] The 2009 annual benzene level was eliminated. The reading measured at each diffusion tube throughout this year was very high due to the fact that they were overexposed and it took a full year to rectify. It was not possible correct this error since it was random.

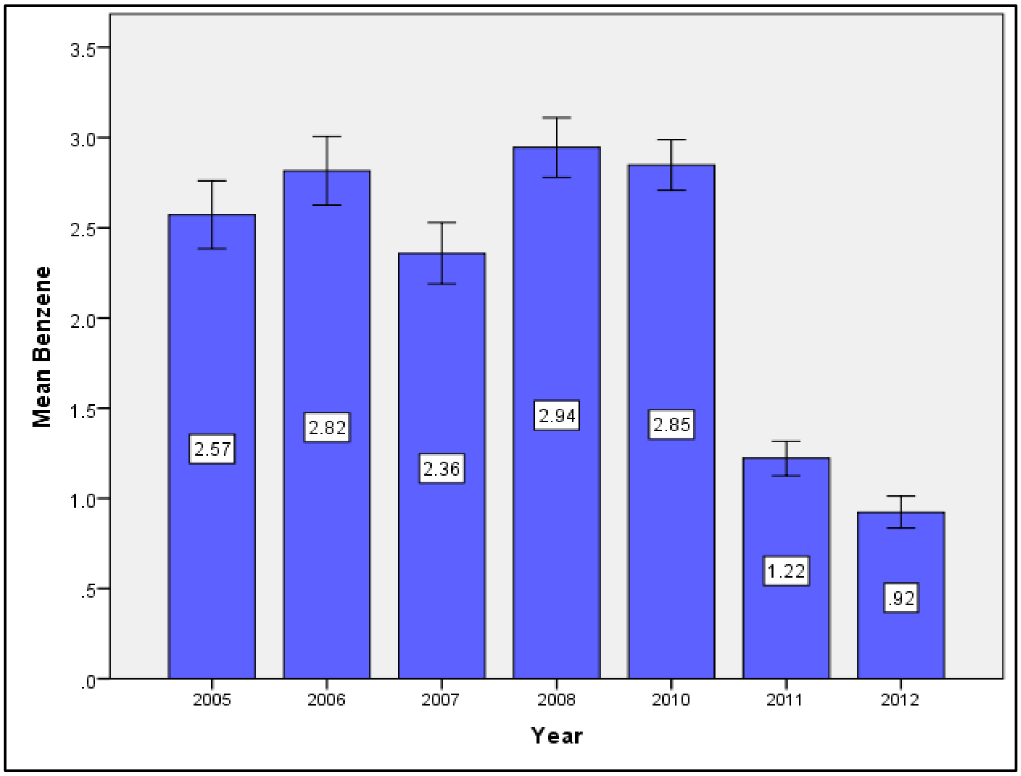

Figure 4.5. - Bar graph showing the benzene means (μg/m^3) between 2005 and 2012 (Source: Author, 2013).

4.2.3 Nitrogen dioxide levels

The readings of the level of nitrogen dioxide concentrations observed in Figure 4.6 seem to be at par with the benzene levels, discussed earlier. A similarity can be noted in the nitrogen dioxide levels. These were also recorded to be relatively higher within the harbour regions and decrease as one moves inland. This outcome could be the result of a heavy traffic flow and large urbanised areas situated in the mentioned regions.

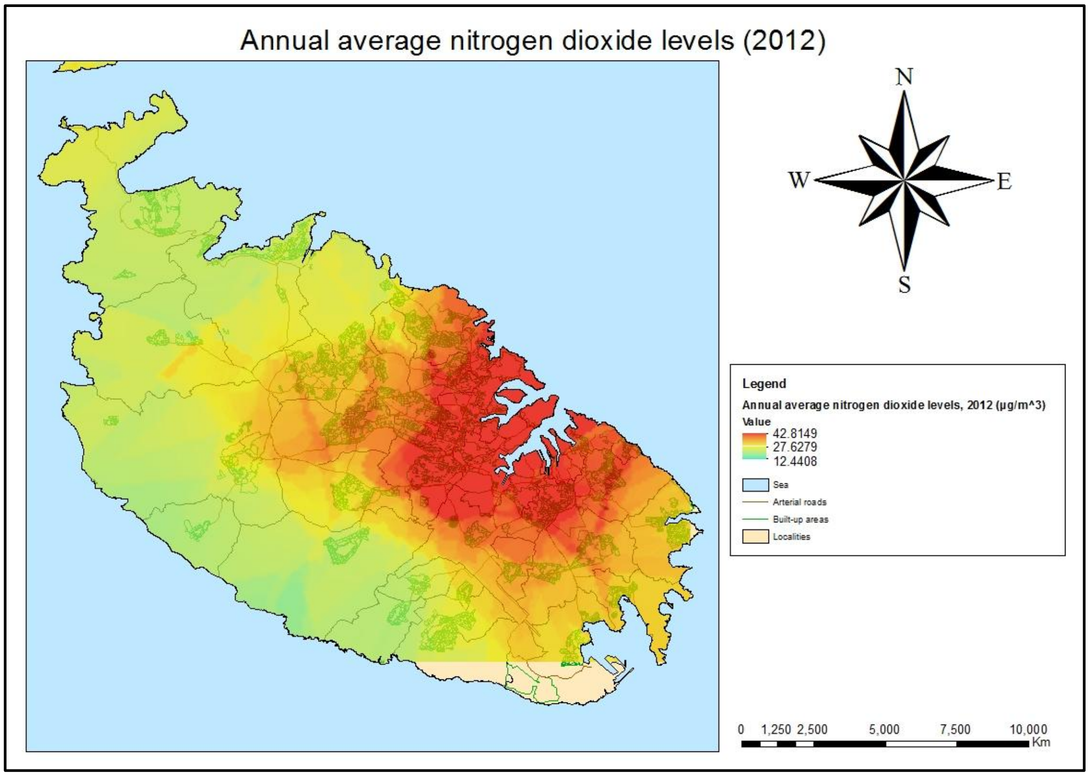

Figure 4.6. - Map showing the recent 2012 annual average nitrogen dioxide levels, µg/m^3 (Source: Author, 2013).

Table 4.5 and Table 4.6 display the results obtained for the nitrogen dioxide levels by the ANOVA statistical test. It can be noted that there the level of nitrogen dioxide is not the same in every locality in such a way that it varies from one place to another. In fact, the variation in the mean nitrogen dioxide levels is considered to be significant since the p-value (≈ 0) obtained from the ANOVA test is lower than the 0.05 significance level. Figure 4.7 displays a bar graph which shows more clearly the average nitrogen dioxide level within the localities that containing the diffusion tubes. The same graphs shows that places such as Floriana, Hamrun and Fgura ranked very high compared with the rest of the localities. In fact, it can be observed that the results obtained by the said statistical test seem to correspond with the distribution of nitrogen dioxide levels displayed in Figure 4.6.

Locality	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Attard	27.869	5.446	1.362	24.967	30.772	20.69	37.90
B' Bugia	22.955	6.865	1.401	20.056	25.853	10.94	34.34
B' Kara	36.871	19.367	3.424	29.888	43.854	18.44	86.37
Bugibba	19.814	5.322	0.841	18.112	21.516	12.64	31.03
Balzan	28.223	3.875	0.969	26.158	30.287	22.14	34.30
Cospicua	37.047	8.284	1.691	33.549	40.545	22.95	49.97
Senglea	33.159	2.772	0.980	30.841	35.477	29.18	36.60
Dingli	13.740	7.404	1.511	10.614	16.867	7.21	26.79
Floriana	59.949	26.168	6.542	46.005	73.893	28.13	95.86
Gudja	26.884	10.161	2.074	22.593	31.174	16.68	44.36
Gzira	35.442	8.293	1.693	31.940	38.944	22.24	47.24
Hamrun	46.894	9.768	1.994	42.769	51.019	30.55	56.57
Kordin	24.840	2.476	.876	22.770	26.910	21.57	28.44
Lija	24.837	4.310	1.077	22.540	27.133	18.82	34.17
Luqa	31.562	4.548	.928	29.642	33.482	20.35	38.87
Mgarr	15.396	2.595	.530	14.300	16.492	11.56	22.36
Mellieha	20.031	14.319	2.923	13.985	26.077	7.87	42.41
Mqabba	21.249	3.599	.900	19.331	23.167	14.26	28.20
Marsa	34.277	5.307	.938	32.364	36.191	23.89	46.51
Msida	33.605	7.673	1.566	30.365	36.845	20.36	44.44
M' Skala	22.538	11.103	2.266	17.850	27.226	12.36	49.22
Mosta	36.528	18.024	3.679	28.917	44.138	11.85	66.28
M' Xlokk	23.826	8.930	1.823	20.056	27.597	10.49	39.36
Naxxar	17.846	4.790	.978	15.823	19.869	10.10	28.42
Paola	27.068	2.616	.654	25.673	28.462	22.51	31.89
Tarxien	30.643	5.486	1.371	27.720	33.566	19.80	37.94
Fgura	44.735	8.093	2.023	40.422	49.048	29.84	55.63
Pieta	32.268	3.806	.777	30.661	33.875	26.43	42.33
Qrendi	11.782	3.157	.789	10.100	13.464	7.60	16.77
Qormi	33.754	10.369	2.117	29.376	38.133	17.48	52.31
Rabat	28.303	16.705	3.410	21.249	35.357	11.35	58.64
Siggiewi	15.692	3.197	.653	14.342	17.042	10.70	23.85

S. Gwann	30.648	10.479	2.139	26.223	35.072	16.14	53.49
Sliema	41.715	13.058	2.665	36.201	47.228	23.19	64.03
Swieqi	26.133	12.976	2.052	21.983	30.282	10.96	50.07
Valletta	28.693	4.099	1.025	26.509	30.877	23.15	36.69
Zebbug	30.265	5.913	1.207	27.768	32.762	21.34	43.36
Zabbar	29.580	14.316	2.922	23.534	35.625	15.73	62.40
Zurrieq	23.074	3.103	0.776	21.420	24.727	16.60	26.84
Safi	13.511	2.270	0.803	11.613	15.409	11.29	18.16
Zejtun	25.603	5.406	0.956	23.654	27.552	17.12	38.23

Table 4.5. - Table showing the descriptives of nitrogen dioxide levels (μg/m^3) with respects to localities containing the diffusion tubes (Source: Author, 2013).

	Sum of Squares	df	Mean Square	F	P-value
Between Groups	73799.306	40	1844.983	18.606	0.000
Within Groups	85575.430	863	99.160		
Total	159374.736	903			

Table 4.6. - Table showing the ANOVA test results for nitrogen dioxide levels (μg/m^3) with respects to localities containing the diffusion tubes (Source: Author, 2013).

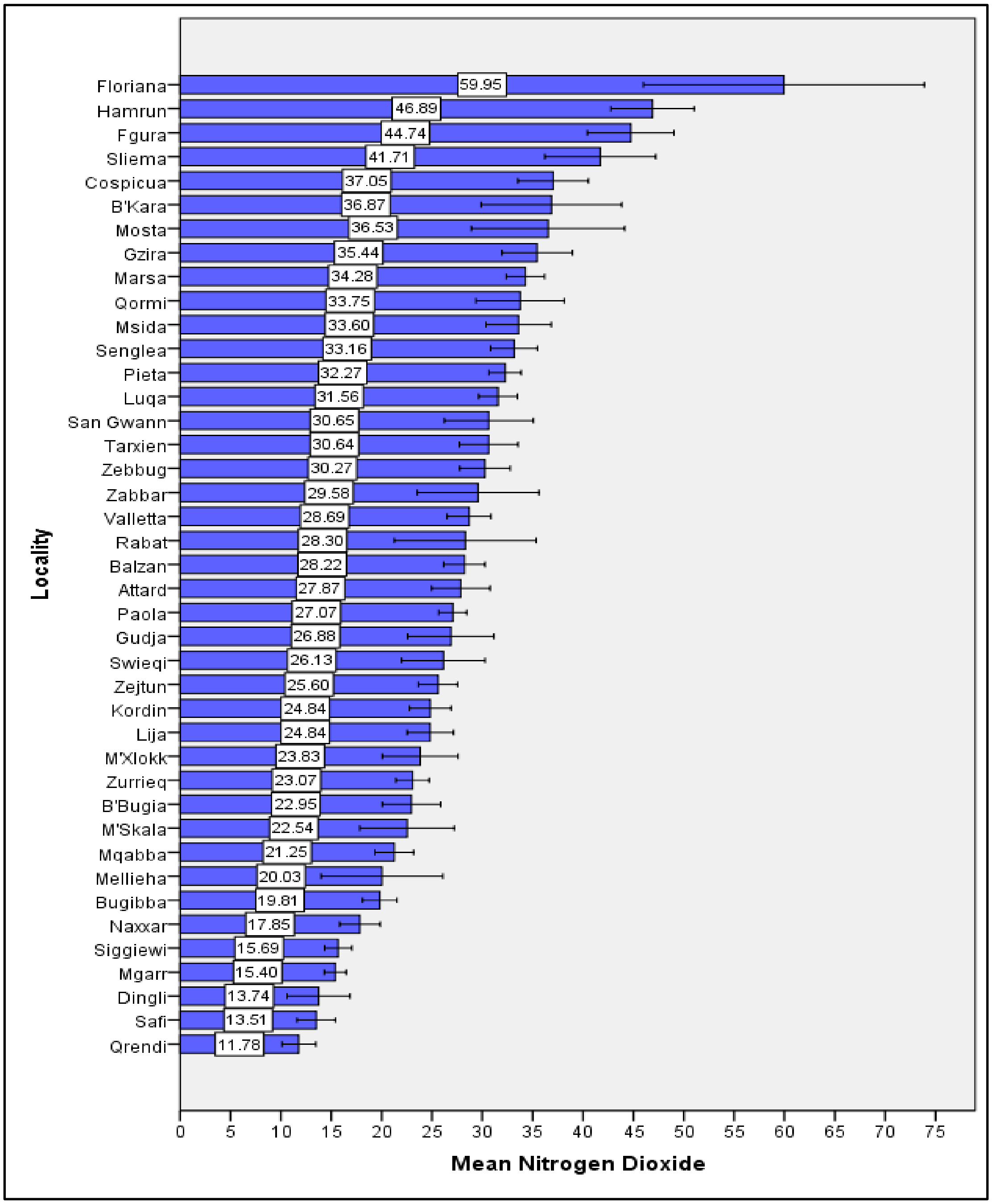

Figure 4.7. - Bar graph showing the mean nitrogen dioxide levels (μg/m^3) in Maltese localities containing the diffusion tubes (Source: Author, 2013).

Figure 4.8 shows the trend of nitrogen dioxide over the past few years, which corresponds to Appendix C. It can be observed that the spatial distribution trend of this pollutant level had remained relatively the same with very minimal changes.

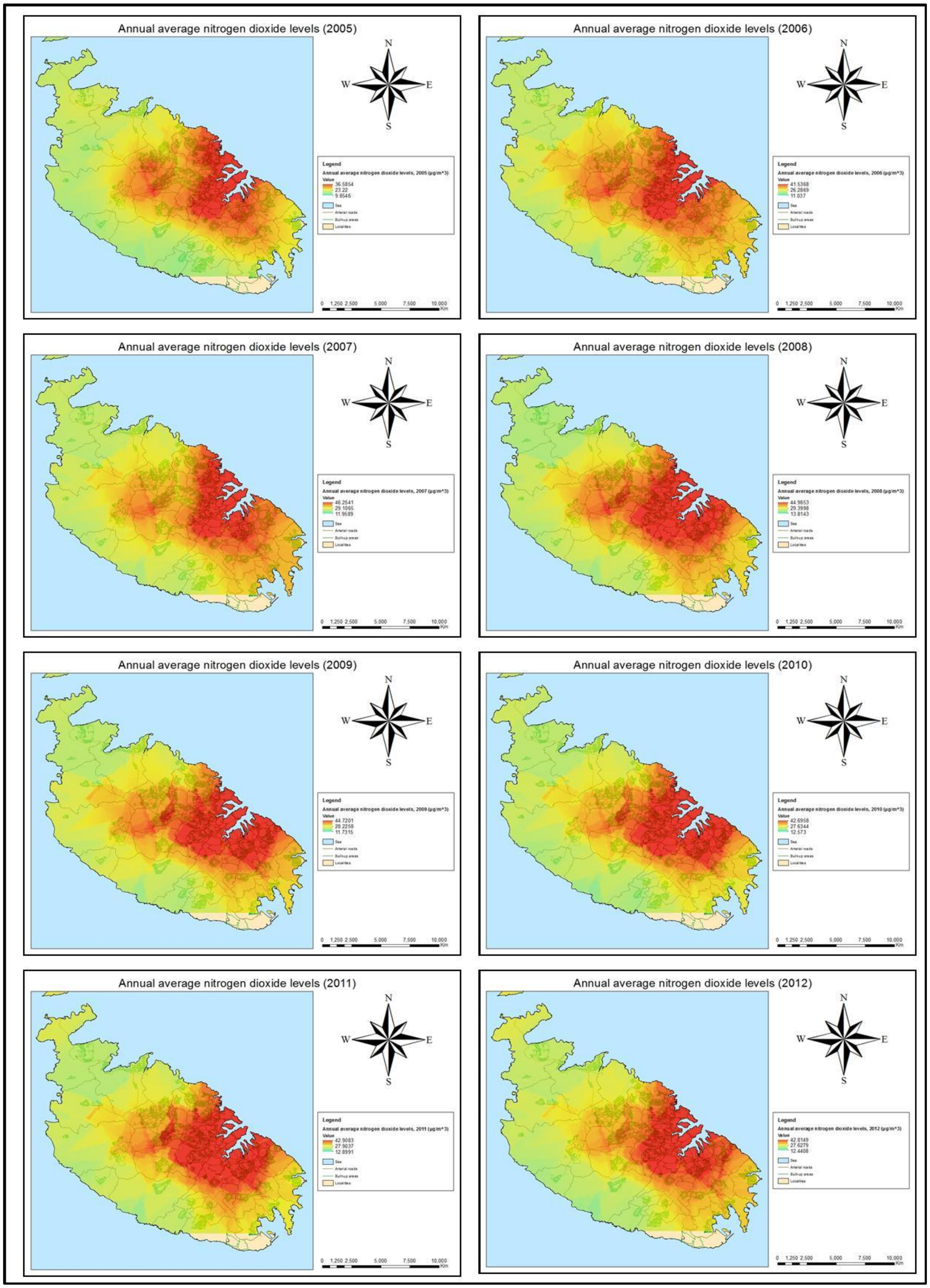

Figure 4.8. - Maps showing the change in annual average nitrogen dioxide levels (μg/m^3) between 2005 and 2012 (Source: Author, 2013).

Table 4.7 shows a summary of the mean levels of nitrogen dioxide measured from each diffusion tube in Malta between 2005 and 2012. The overall trend shows that at nitrogen dioxide seems to have increased until it reached a peak value of 30.812 μg/m^3 in 2007. This however appeared to have decreased from than onwards, with some slight variations, as shown in Figure 4.9. The change in the mean levels of nitrogen dioxide can be considered to be significant since the p-value (≈ 0), which is displayed in Table 4.8, is less than the 0.05 level of significance. Moreover, it is important to point out that the levels of nitrogen dioxide did not exceed the annual level of 40 μg/m^3 set up by the Ambient Air Quality Directive in 2008. Nevertheless, there is still the need for more enforcement to decrease the level of this air pollutant in upcoming years.

Year	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
				Lower Bound	**Upper Bound**		
2005	24.537	11.199	1.053	22.449	26.624	8.65	75.91
2006	27.471	12.709	1.196	25.102	29.840	7.39	93.48
2007	30.924	13.459	1.266	28.415	33.433	8.47	81.98
2008	30.812	12.838	1.208	28.419	33.205	9.27	80.37
2009	29.435	14.860	1.398	26.665	32.204	7.60	95.86
2010	28.383	13.511	1.271	25.865	30.901	7.21	83.85
2011	28.174	13.712	1.290	25.618	30.730	7.88	88.75
2012	28.516	13.018	1.225	26.089	30.942	8.30	81.46

Table 4.7. - Table showing the descriptives of nitrogen dioxide levels (μg/m^3) with respect to time (Source: Author, 2013).

	Sum of Squares	**df**	**Mean Square**	**F**	**P-value**
Between Groups	3273.707	7	467.672	2.684	0.009
Within Groups	156101.029	896	174.220		
Total	159374.736	903			

Table 4.8. - Table showing the ANOVA test results for nitrogen dioxide levels (μg/m^3) with respects to time (Source: Author, 2013).

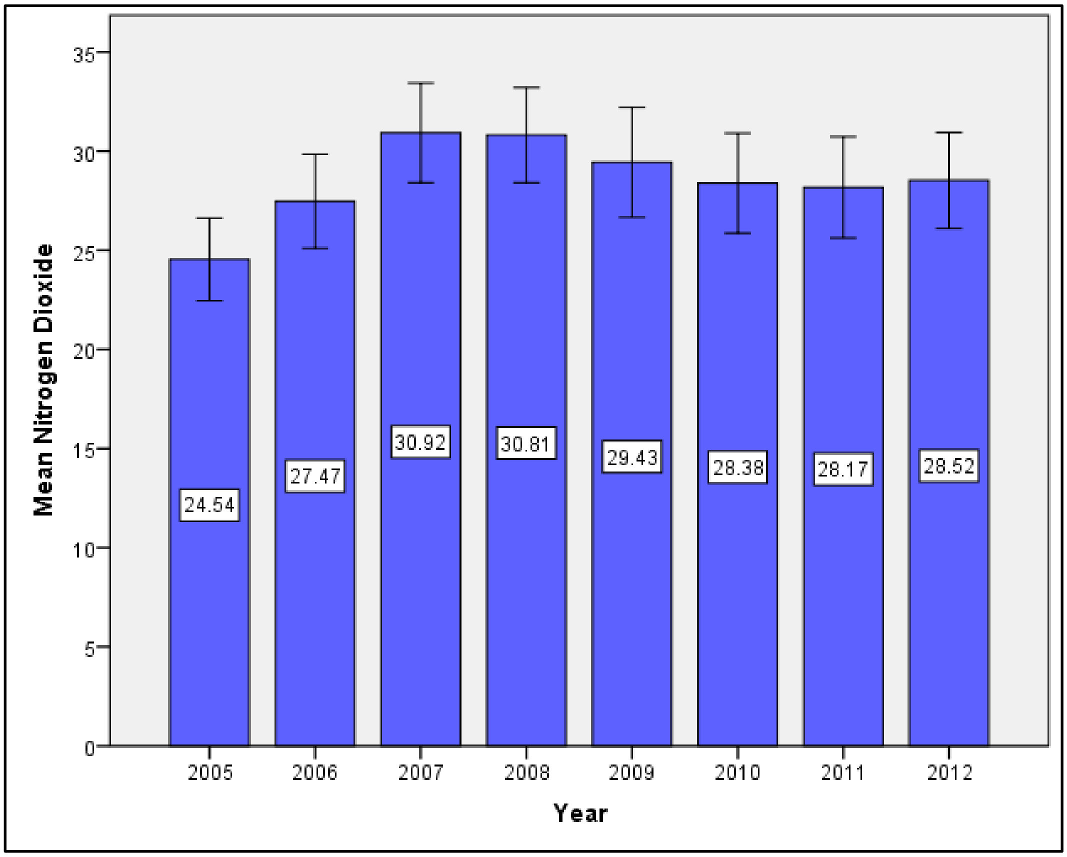

Figure 4.9. - Bar graph showing the benzene means (µg/m^3) between 2005 and 2012 (Source: Author, 2013).

4.2.4 Correlation of benzene and nitrogen dioxide level trends

Pearson's (*r*) correlation, which was discussed earlier on, was applied to analyse the actual relationship between benzene and nitrogen dioxide levels. Variable X was substituted with the nitrogen dioxide levels, whereas variable Y was substituted with the benzene levels. A scatter plot was produced (Figure 4.10) to show their correlation. It displays a clear positive linear relationship between the concentrations of both air pollutants and it shows that there is a large values of benzene levels, when the nitrogen dioxide levels are high. The Pearson's *r* correlation co-efficient (0.603) is significantly different from zero since the p-value ($\approx$ 0), displayed in Table 4.9, is less than the 0.05 level of significance.

		Nitrogen Dioxide
Benzene	**Pearson Correlation**	0.603
	P-value	0.000

Table 4.9. - Table showing the Pearson's correlation between benzene and nitrogen dioxide levels (Source: Author, 2013).

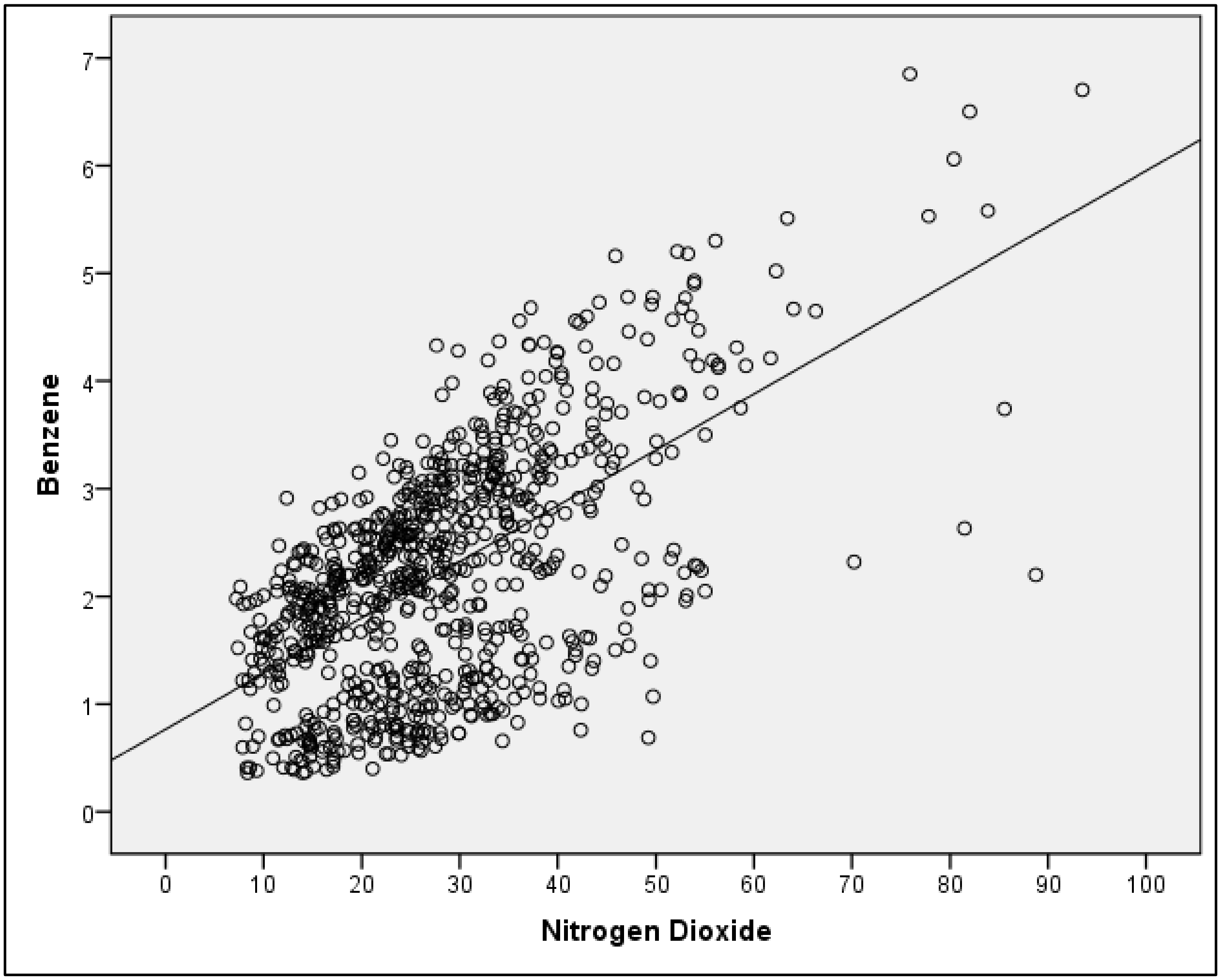

Figure 4.10. - Scatter plot showing Pearson's correlation between the levels of benzene and nitrogen dioxide (Author, 2013).

4.3 Analysis of the perceived questionnaire data

4.3.1 Demographics

The perceived data was gathered from a number of questionnaires which was shared online in which it was replied by a number of 412 respondents. From the collected sample of the said questionnaires, some observations regarding the demographics were made as follows:

- Age Group

Age groups were classified as indicated in Table 4.10. The contribution towards these questionnaires came mainly from young adults and amounted towards 44.17% of the respondents in total. Another point of interest is the fact that the higher in age the group is the less respondents participated to the survey. This could be due to the fact that there are less computer-literate persons within the older generations (Slegers *et al*., 2012).

Age groups	**Percentage of respondents (%)**
18-27	44.17
28-37	24.51
38-47	15.53
48-57	10.19
58-67	4.85
68+	0.73

Table 4.10. - Table showing percentage of respondents with respect to age groups (Source: Author, 2013).

- Gender

The data gathered from the questionnaire shows that the majority of the respondents were females, which accounted for more than 57%, whereas males only accounted for approximately 42.2%. On the other hand, only two respondents (0.5%) out of the whole questionnaire sample preferred not to state their gender. This is better indicated on Table 4.11, displayed below.

Gender	Percentage of respondents (%)
Female	57.28
Male	42.23
Prefer not to answer	0.49

Table 4.11. - Table showing percentage of respondents with respect to gender (Source: Author, 2013).

- Home localities

Table 4.12 shows a summary of the percentage of respondents with respect to the localities with which they reside. From the survey, it can be noted that the highest number of respondents results from St. Paul's Bay with an outcome of 5.58%. This percentage was followed by respondents from Birkirkara and Mosta, resulting to 5.10% and 4.37% respectively.

Home locality	Percentage of respondents (%)	Home locality	Percentage of respondents (%)
Attard	3.40	Mqabba	1.21
Balzan	0.97	Msida	2.91
Birgu	0.73	Mtarfa	1.21

Birkirkara	5.10	Naxxar	1.94
Birzebbuga	1.46	Paola	1.21
Bormla	0.73	Pembroke	0.73
Dingli	0.73	Pieta'	0.73
Fgura	2.67	Qormi	2.67
Floriana	0.73	Qrendi	0.97
Gharghur	1.70	Rabat	1.70
Ghaxaq	1.21	Safi	0.97
Gudja	1.21	San Gwann	2.67
Gzira	1.21	Santa Lucija	1.46
Hamrun	1.46	Santa Venera	1.94
Iklin	1.21	Siggiewi	2.91
Isla	0.73	Sliema	3.16
Kalkara	0.97	St. Julian's	3.40
Kirkop	0.97	St. Paul's Bay	5.58
Lija	0.97	Swieqi	2.91
Luqa	1.46	Ta' Xbiex	0.97
Marsa	0.97	Tarxien	1.94
Marsaskala	2.67	Valletta	0.73
Marsaxlokk	1.94	Xghajra	0.97

Mdina	1.46	Zabbar	3.16
Mellieha	2.18	Zebbug	2.18
Mgarr	1.21	Zejtun	1.70
Mosta	4.37	Zurrieq	3.64

Table 4.12. - Table showing percentage of respondents with respect to their home locality (Source: Author, 2013).

- Occupation

Respondents in the survey were also classified in terms of their occupation. A large number consisting of 58.01% of the respondents consisted of employed individuals. The second largest group of the same category was students. In this case, 23 % of these students contributed towards the survey. This was followed by a mere number of 8.50% contribution from house and/or family carers. The percentage of respondents with respect to their occupation can be observed clearly on Table 4.13.

Occupation	**Percentage of respondents (%)**
Employed	58.01
Retired	3.64
Self-employed	3.64
Student	23.30
Taking care of a family and/or a house	8.50
Unemployed	2.91

Table 4.13. - Table showing percentage of respondents with respect to their occupation (Source: Author, 2013).

- Level of education

A lot of respondents who answered the questionnaire were mostly individuals with a tertiary level of education, amounting to 38.59% of the total obtained responses. This was followed by post-graduates, which amounted to 30.34%, where as the third highest were those who had a post-secondary level of education (19.9%). These percentages shown below in Table 4.14.

Level of education	Percentage of respondents (%)
Primary	0.24
Secondary	10.68
Post-Secondary	19.90
Tertiary	38.59
Post-Graduate	30.34
Others	0.24

Table 4.14. - Table showing percentage of respondents with respect to their level of education (Source: Author, 2013).

4.3.2 Perception of the current level of air quality

The respondents of the questionnaires were asked to gauge freely the current level of air quality of Malta and certain localities[23] from a scale of one to ten. This scale was made in a way to shift towards good air quality as it ascends. Figure 4.11 displays a graph showing the replies of each respondent for each place. At first glance, one would notice that there are a lot of various answers due to the fact, that air quality is considered to be a main concern.

If one had to notice the respondents' views on the state of air quality in Malta in Figure 4.11, it can be observed that the majority (23.3%) ranked the air quality level at number

[23] These localities were listed earlier on in Section 3.3.

five. This means that most of the respondents view the level of present national air quality as moderate, i.e. not being very good neither very poor. Figure 4.11 also displays the relationship between the respondents and their perceived gauge levels of the current air quality in other specific localities. It seems that all of the nine localities resulted to have a lot of variations with regards to the present air quality level. A large percentage of respondents appear to associate Birkirkara, Marsa, Paola, Sliema and Valletta with poor air quality. Marsa seems to have the largest percentage of respondents gauging it with number one, with 37.14%. This was followed by Paola and Sliema, contributing to 19.66% and 13.35% respectively. On the other hand, localities such as Mellieha and Rabat were perceived to have a good level of current air quality. This was disclosed by 16.26% of the all respondents in terms of Mellieha and 9.71% in terms of Rabat. Furthermore, the respondents seemed to have mixed feelings about the state of air quality in term of Marsaxlokk and Mosta. In fact, the majority of respondents gauged the state of air quality in these two localities at a level of 5.

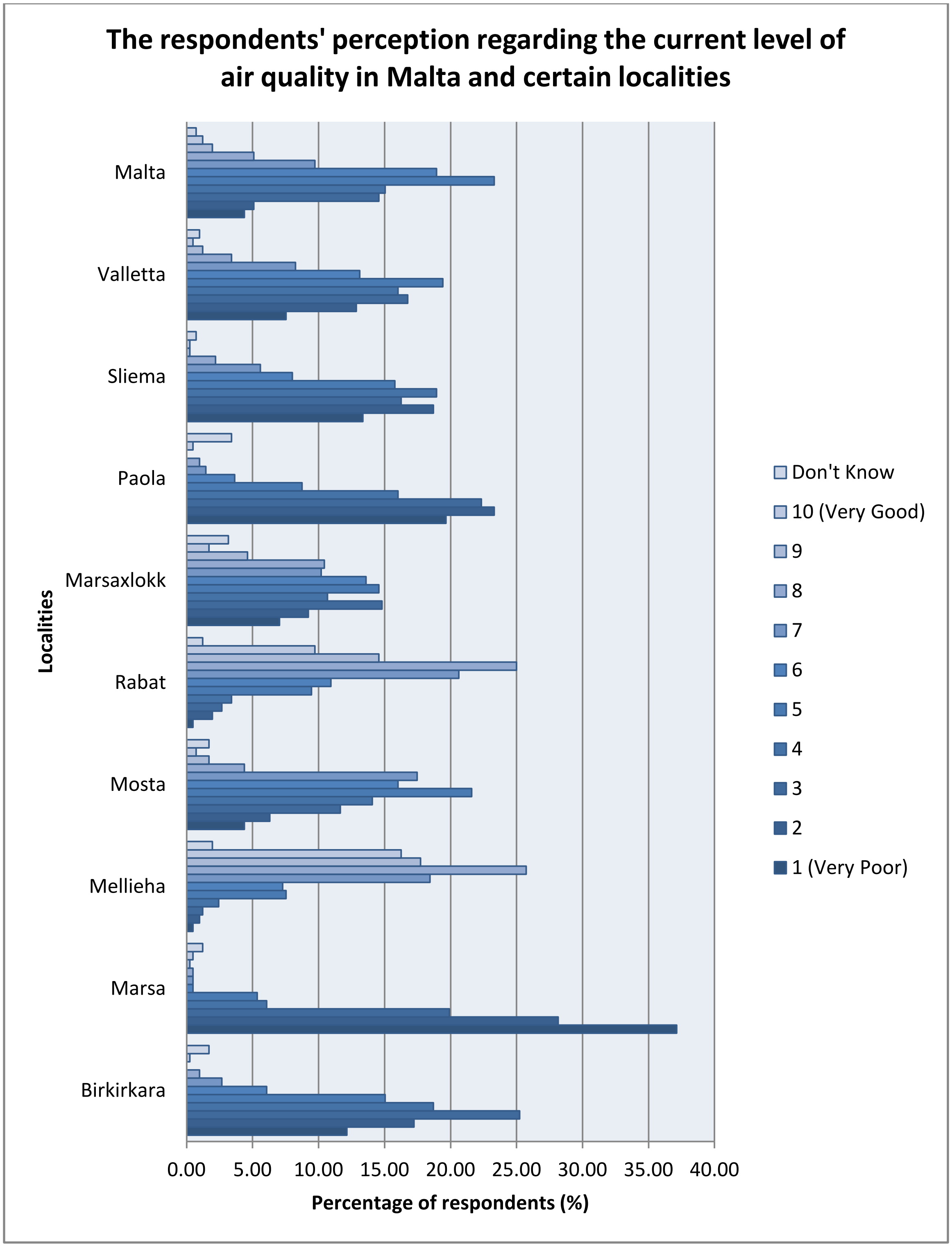

Figure 4.11. - Bar graph showing the respondents' perception regarding the current level of air quality in Malta and certain localities (Source: Author, 2013).

Friedman statistical test was applied for each of the above mentioned places with a result as can be observed in the two subsequent tables. Table 4.15 displays the mean gauge level perceived by the respondents for each appropriate location, which seem to vary from one another. This variation of the mean gauge level of the current state of air quality perceived by the respondents varies significantly amongst the mentioned places since the p-value (≈ 0), as shown in Table 4.16, is lower than 0.05 level of significance. Figure 4.12 shows a clearer representation of the tabulated results and it can be observed that places such as Mellieha and Rabat were perceived with a higher level of air quality compared to other localities. Moreover, if one had to observe the perceived air quality level of Malta, as indicated in red, it can be noted that it ranked approximately in the middle.

Place	Mean	Standard Deviation
B' Kara	3.43	1.609
Marsa	2.22	1.400
Mellieha	7.67	1.815
Mosta	4.95	1.881
Rabat	7.18	1.911
M' Xlokk	4.91	2.332
Paola	2.94	1.581
Sliema	3.59	1.841
Valletta	4.21	1.907
Malta	4.86	1.874

Table 4.15. - Table displaying the mean gauge level of the current state of air quality in each respective location according to the respondents (Source: Author, 2013).

Sample size	379
Chi-Square	2186.541
df	9
P-value	0.000

Table 4.16. - Table displaying the Friedman test for the mean gauge level of the current state of air quality (Source: Author, 2013).

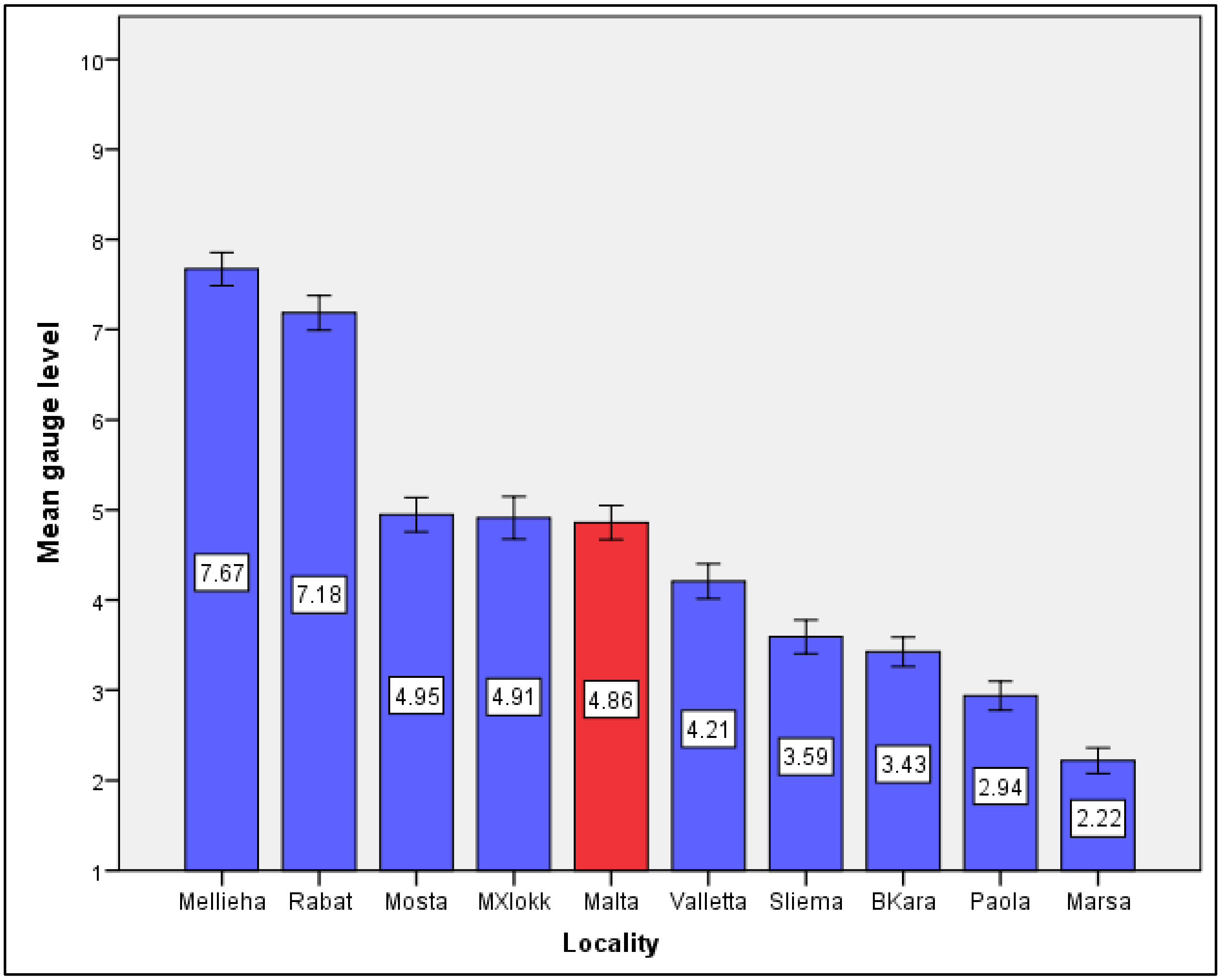

Figure 4.12. - Bar graph displaying the mean gauge level of the current state of air quality in each respective location according to the respondents [NB: 1: very poor AQ & 10: very good AQ]. (Source: Author, 2013).

The gauge level of the current state of air quality provided by the respondents for Malta and the nine localities was correlated with level of benzene and nitrogen dioxide taken from the diffusion tubes averaged across the years. This was done by using Pearson's *r* correlation statistical test which as a result, lead to the formation of the following Table 4.17 and the scatter plots (Figure 4.13 & Figure 4.14). The Pearson's correlation co-efficient measuring the relationship between benzene and the current gauge level of air quality (-0.413) is negative indicating that low gauge scores were provided for high benzene concentrations, whereas high gauge levels were provided for low benzene concentrations. Similarly, the Pearson's correlation co-efficient measuring the relationship between nitrogen dioxide and the gauge level (-0.574) is negative indicated that low gauge scores were provided for high nitrogen dioxide levels and high gauge scores were provided for low nitrogen dioxide levels.

		Current state of air quality gauge level
Benzene	**Pearson Correlation**	-0.413
	P-value	0.236
Nitrogen Dioxide	**Pearson Correlation**	-0.574
	P-value	0.082

Table 4.17. - Table showing the Pearson's correlation of benzene and nitrogen dioxide with the current state of air quality gauge level perceived by the respondents (Source: Author, 2013).

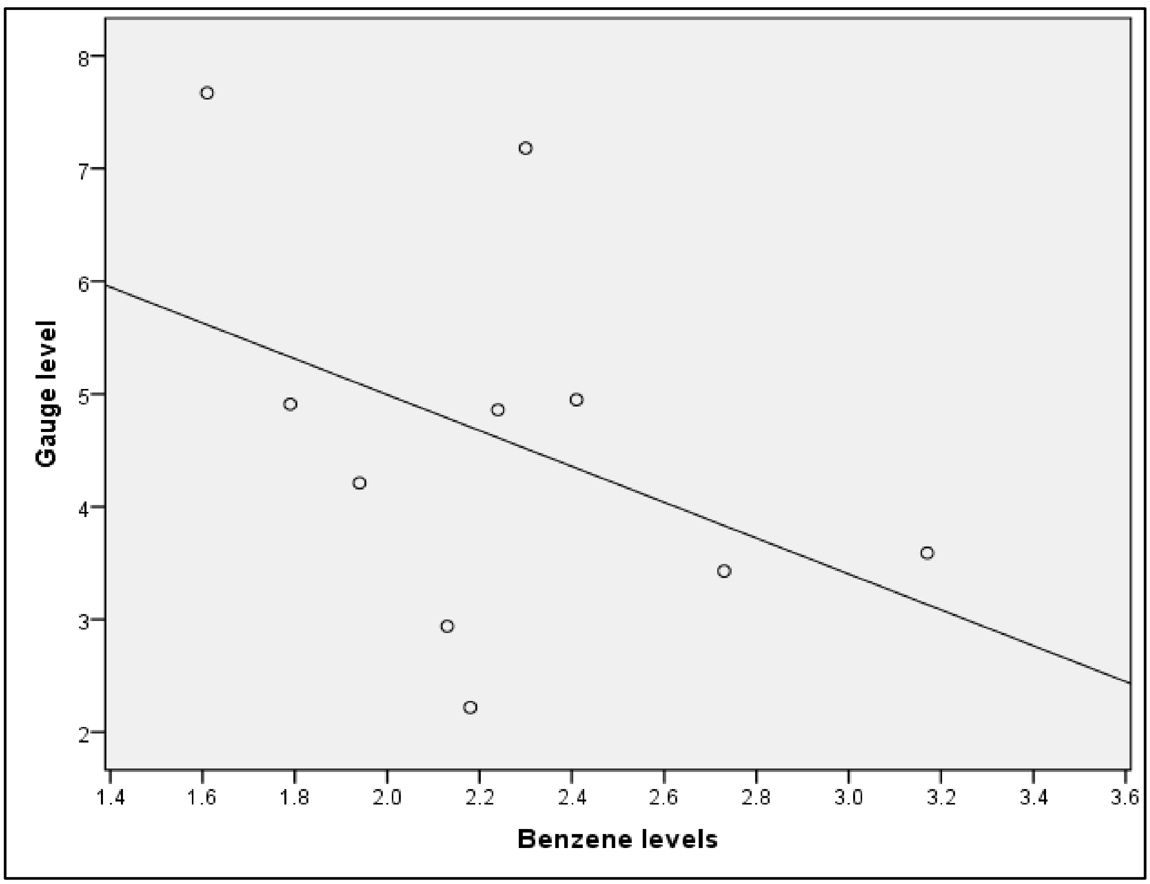

Figure 4.13. - Scatter plot showing the Pearson's correlation of benzene with the current air quality gauge level perceived by the respondents [NB: 1: very poor AQ & 10: very good AQ] (Source: Author, 2013).

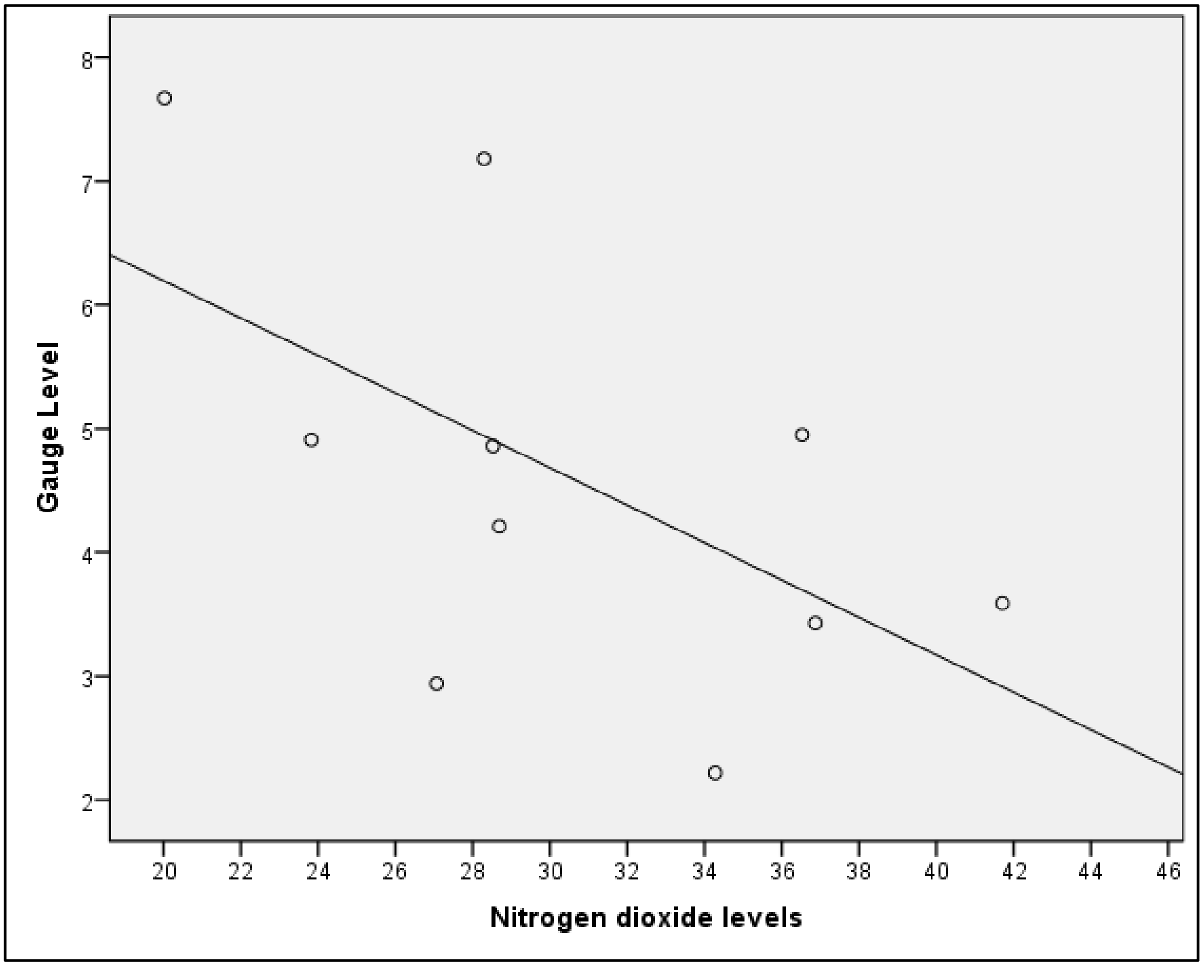

Figure 4.14. - Scatter plot showing the Pearson's correlation of nitrogen dioxide with the current air quality gauge level perceived by the respondents [NB: 1: very poor AQ & 10: very good AQ] (Source: Author, 2013).

4.3.3 Perception of the change in level of air quality

Figure 4.15 shows a bar graph which displays the perceived change in level of the air quality over the previous three years in Malta and nine specific localities. With regards to the change of air quality state in Malta, most of the respondents had ranked it with number 5, meaning that the change in the national air quality was moderate over the past three years. This change was accounted for by 25% of the respondents. However, if the graph in Figure 4.15 was observed closely, one would notice that more respondents consider that the air quality in level in Malta had rather deteriorated than improved over the same time period.

The respondents were also asked to gauge the change in levels of air quality in the other previously mentioned nine localities. The perceived data by each respondents is indicated better in Figure 4.15. Marsa was perceived to be the top locality to experience a decline in its regional level of air quality. In fact, 24.27 % of the respondents ranked this locality with number 1. This was followed shortly by Paola (15.05%) and Sliema (14.32%) of whom respondents also selected number 1. In contrast, 7.52% of the respondents said that Mellieha had an improved level of air quality over the said time period. This was followed by Rabat, whereby 5.83% of respondents also gauged the change in level of air quality as number 10.

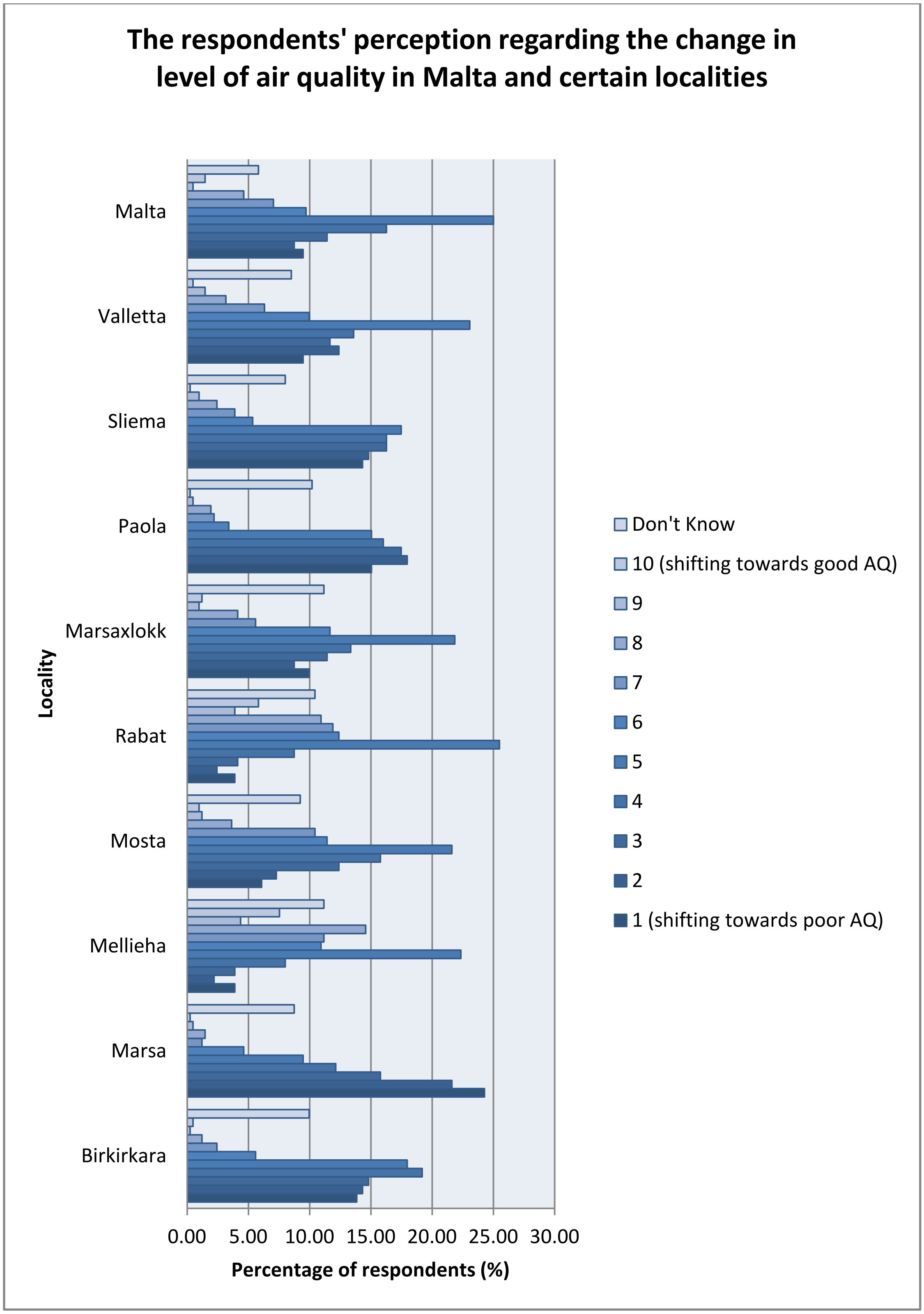

Figure 4.15. - Bar graph showing the respondents' perception regarding the change in level of air quality in Malta and certain localities over the previous three years (Source: Author, 2013).

Friedman statistical test was applied for each of the above mentioned locations. Table 4.18 and Table 4.19 were produced. Table 4.18 displays the mean gauge level with regards to the change in air quality level perceived by the respondents for each appropriate location. The results of the mean gauge level on the change in the state of air quality perceived by the respondents varies significantly amongst the mentioned places since the p-value (≈ 0), as shown in Table 4.19, is lower than 0.05 level of significance. Figure 4.16 shows a clearer representation of the tabulated results and it can be observed that places such as Mellieha and Rabat were selected again as the two top localities which experienced an improvement in their local state of air quality in comparison with the other localities. Moreover, if one had to observe the perceived change in air quality level of Malta, as indicated in red, it can be noted that it ranked almost in the middle.

Place	Mean	Standard Deviation
B'Kara	3.59	1.795
Marsa	2.91	1.792
Mellieha	6.03	2.283
Mosta	4.62	1.982
Rabat	5.79	2.185
M'Xlokk	4.36	2.088
Paola	3.36	1.808
Sliema	3.66	1.953
Valletta	4.15	1.999
Malta	4.38	2.030

Table 4.18. - Table displaying the mean gauge level of the change in air quality state in each respective location according to the respondents (Source: Author, 2013).

Sample Size	346
Chi-Square	1171.231
df	9
P-value	0.000

Table 4.19. - Table displaying the Friedman test for the mean gauge level of the change in air quality state (Source: Author, 2013).

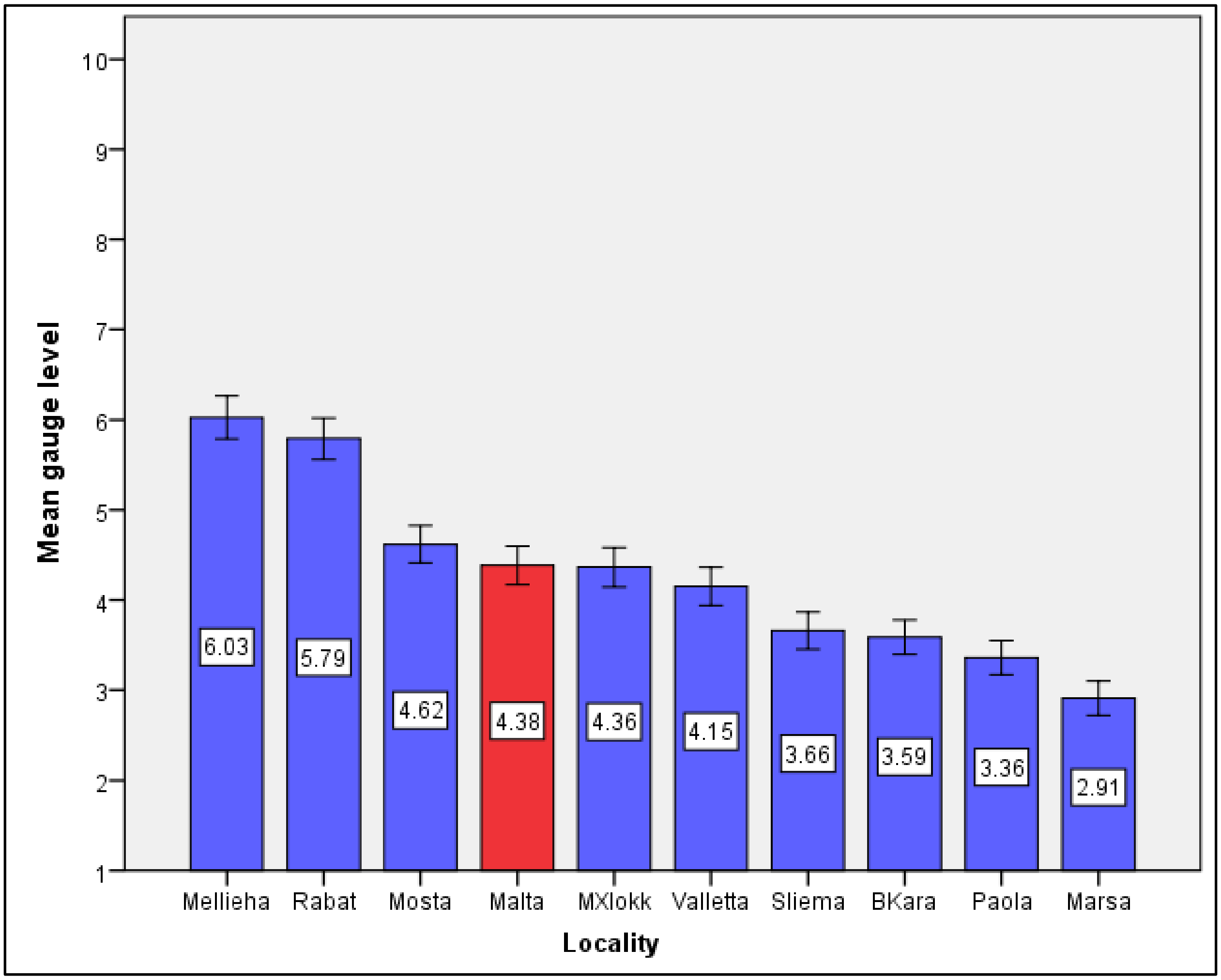

Figure 4.16. - Bar graph displaying the mean gauge level of the change in state of air quality in each respective location according to the respondents [NB: 1: shifting towards poor AQ & 10: shifting towards good AQ]. (Source: Author, 2013).

Similarly to the previous section, the gauge level of the change in air quality state provided by the respondents for Malta and the nine localities was correlated with levels of benzene and nitrogen dioxide taken from the diffusion tubes average across the years by the use of Pearson' *r* correlation co-efficient (Table 4.20). As a result, the following tables and scatter plot graphs were produced. The Pearson's *r* correlation co-efficient (Figure 4.17) measuring the relationship between change in benzene levels and the change in air quality gauge level (-0.412) is negative indicating that low gauge scores were provided for high benzene concentrations, whereas high gauge levels were provided for low benzene concentrations. Similarly, the Pearson's correlation co-efficient (Figure

4.18) measuring the relationship between the change in nitrogen dioxide levels and the change in gauge level (-0.559) is negative indicated that low gauge scores were provided for high nitrogen dioxide levels and high gauge scores were provided for low nitrogen dioxide levels.

		Change in state of air quality gauge level
Benzene	**Pearson Correlation**	-0.412
	P-value	0.237
Nitrogen Dioxide	**Pearson Correlation**	-0.559
	P-value	0.093

Table 4.20. - Table showing the Pearson's correlation of benzene and nitrogen dioxide with the change in state of air quality gauge level perceived by the respondents (Source: Author, 2013).

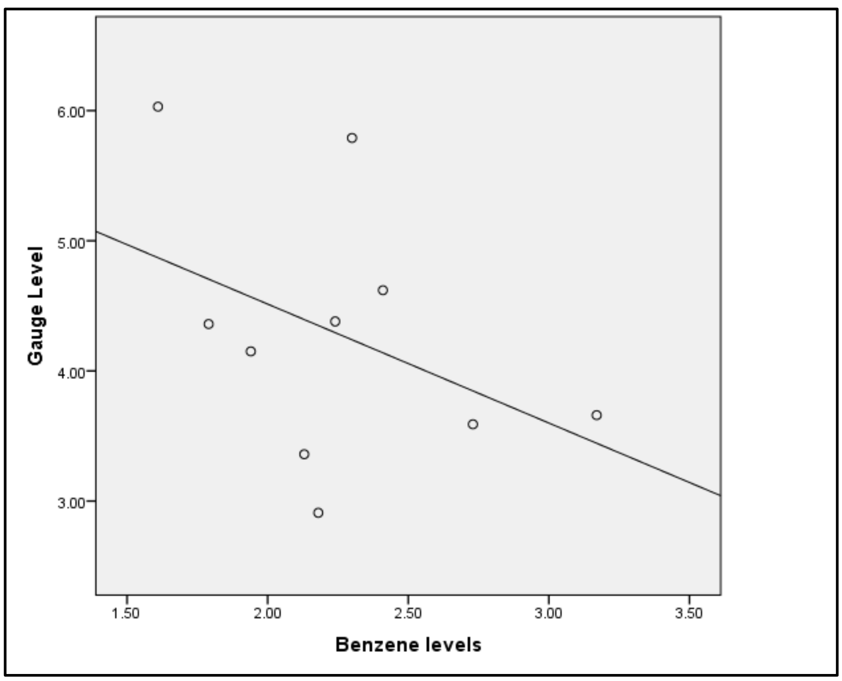

Figure 4.17. - Scatter plot showing the Pearson's correlation of benzene with the change in air quality gauge level perceived by the respondents [NB: 1: shifting towards poor AQ & 10: shifting towards good AQ] (Source: Author, 2013).

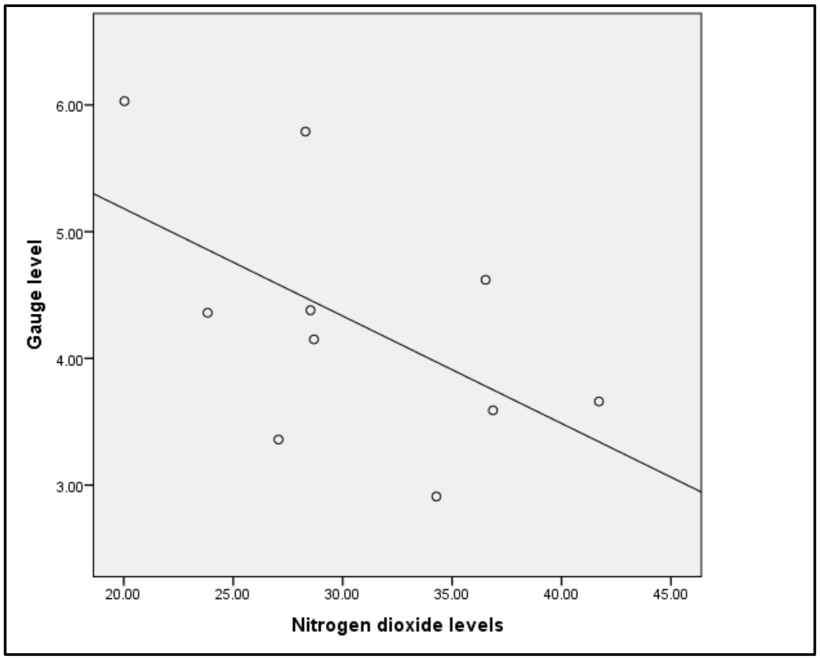

Figure 4.18. - Scatter plot showing the Pearson's correlation of nitrogen dioxide with the change in air quality gauge level perceived by the respondents [NB: 1: shifting towards poor AQ & 10: shifting towards good AQ] (Source: Author, 2013).

4.3.4 Perception of the current level of air quality in the respondents' home localities

The respondents were also asked to gauge their current state of air quality in their home locality. There seems to be a lot of different opinions on the current quality of air with respect to the respondents' home locality, as per Appendix D. In fact, it appears that each of respondents' answer corresponds with their residing locality. The following observations were made:

- the perceived quality of air seems to be very poor in places that are in the vicinity of the Grand and Marsamxett Harbours such as Msida, Fgura, Hamrun and St. Julian's;
- the perceived level of air quality seems to be variable in places which are a bit distant from the harbour districts such as Attard, Ghaxaq and Qormi; and
- the perceived level of air quality seems to be very good in places which are situated the furthest out from the said region, such as Mgarr, Zurrieq and St. Paul's Bay.

As one can notice, the respondents perceive the level of air quality in specific locality depending on its position. It can be noted that according to the respondents, the air quality level is bad within the agglomerate and urbanised harbour areas of Malta and improves as one moves outwards.

4.3.5 Socio-demographic analysis of the current level of air quality in the respondents' localities

The tabulated results in Appendix D display the relationship between the socio-demographics of the respondents and their views on the current state of air quality with their home localities. It seems that the majority of the younger generation tend to think that the level of air quality in their residing locality is slightly to relatively good. However, respondents between the age of 58 and 67 tend to oppose this view. In fact, 35% of this group have gauged the air quality with a level of 2. According to these respondents, the level of air quality in their locality seems to be almost very poor. It seems that most of the females respondents (17.37%) have gauged the status of the current air quality in their residing locality with a level of 7. They consider their local air quality to be quite good. Similarly, it seems that males consider their local level of quality to be quite good as well, with 14.37% gauging it at a level of 7.

The majority of the respondents which are employed (12.55%), self-employed (33.33%), students (15.63%) and house carers (17.14%) tend to think that the current air quality level in their locality is quite good. On the other hand, most of the respondents who are pensioners had perceived that the present status of their local air quality is almost very poor. Moreover, 33.33% of the unemployed respondents had gauged their local air quality with a level of 5 and therefore, considering it as moderate. According to the obtained results tabulated in Appendix D, it appears that most of the respondents who remained longer in education had perceived that the current status of air quality in their home localities to be slightly better than moderate. In fact, 15.2% of post-graduates, 17.61% of graduates and 15.85% of individuals which have a post secondary level of education have gauged their local air quality with a level of 7. In contrast, 18.18% of the respondents with secondary education background think that the level of the air quality in their residing locality is almost very poor.

4.3.6 Perception of the change in level of air quality of respondents' home localities

In the questionnaire, the respondents were also asked to rank the change in state of air quality in their home locality over the past three years. The outcome results regarding this change turned out to be various amongst the residing localities of the respondents, as per Appendix E. In fact, there are various perceived changes which vary according to their position on the island. From the collected data, it can be observed that residents were noted to have:

- poor current level of air quality, had a experienced a decline in the level of air quality;
- moderate current level of air quality, had also experienced a decline; and
- good current level of air quality, had rather experienced an improvement.

Hence, it can be noted that the majority of the respondents think that the level of air quality had relatively decreased over the previous years, mainly those who live in vicinities of the developed, agglomerate areas of Malta.

4.3.7 Socio-demographic analysis of the change in level of air quality in the respondents' home localities

This analysis is based on the tabulated results presented in Appendix E. It can be observed that the majority of all age groups had gauged the change of air quality in their home locality at a level of 5. This means that all of these respondents consider the change to be reasonable. However, it also seems that most of the respondents belonging to an older generation (58-67 years) think that the localised change of air quality level had decreased as well. Moreover, both respondents of the same gender think that the said change is moderate. In facts, the results show that 25.85% and 23.56% of female and male respondents have gauged the change at level of 5 respectively.

With regards to the occupation groups, all of them seem to think that there were moderate changes in their local air quality level. However, 26.67% of the respondents who are self employed think that the air quality change had slightly worsened. Respondents with a post-secondary education or higher tend to think that there was a moderate change in their local level of air quality. In contrast, the majority of the respondents with a secondary level of education differ with this view. In fact, 29.55% of these respondents consider that there was a deterioration in the air quality level of their home localities.

4.3.8 Sources of information

From the results shown in Figure 4.19, the major source of information of the respondents regarding air quality in each location was through personal observation. However, it seems that perceived source of information regarding the level of air quality was mostly dominant in each of the respondents' residing locality (90.05%). On the other hand, it appears that media ranked second place in every mentioned location, whereas education ranked third place. In addition, one can notice that according to the survey, the media was a powerful source of information in terms of Marsa and Marsaxlokk[24]. Also, it can be noted that the respondents stated that education seemed to be a minimal source of information with regards to the level of air quality in all places.

In the survey, any other source of information was catagerorised under the tile of 'others'. The respondents who participated under this category claimed that they got to know about the air quality in these places through blogs, discussion with experts, word of mouth, MEPA sources[25] and a combination of all the possible sources. Some of these respondents who selected 'others', also stated that they got to know about the quality of air in these areas through comparison with the sister island of Gozo and other foreign countries.

[24] This might be due to the fact that these localities are home to the two power stations, which are frequently reported on the news and newspapers.

[25] Namely, the 2008 State of the Environment Report (MEPA, 2010).

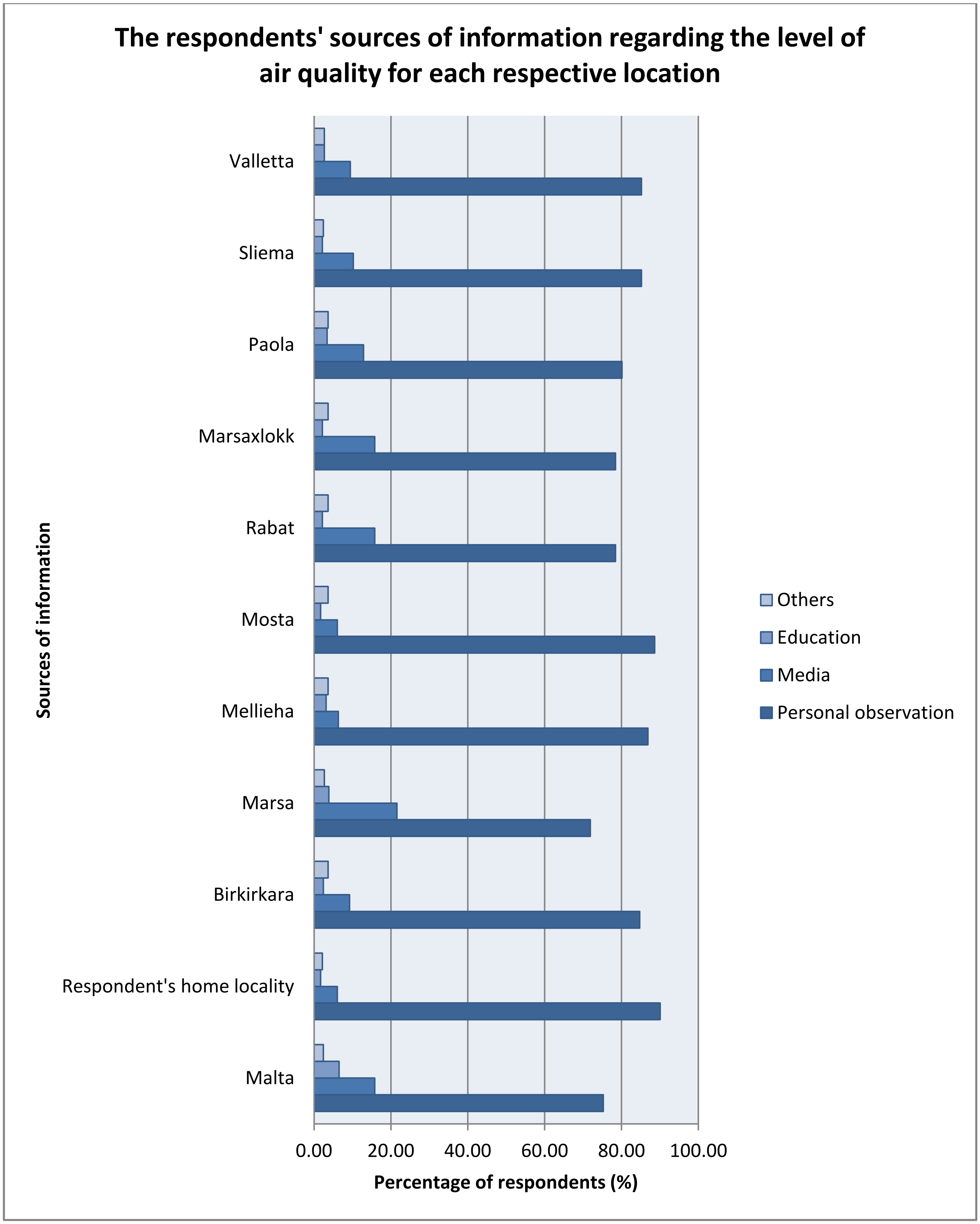

Figure 4.19. - Bar graph showing the respondents' sources of information regarding the level of air quality for each respective location (Source: Author,2013).

4.3.9 Contributors of air pollution

Figure 4.20 shows the perceived contributors of air pollution in the respondents' home localities. At first glance, one can notice that the top contributor of air pollution is on-road vehicles. This was perceived by 30.26% of the respondents who also argued that emissions from cars, buses, trucks and other modes of transport are contributing significantly to poor levels of air quality.

The second major contributor of air pollution according to the respondents seemed to be construction works and quarries (12.38%). These include both construction of buildings and of major roads. These respondents argued that this contributor is an emitter of dust, which continues to cause adverse health impacts such as asthma, which will be discussed further on.

The third largest perceived contributor of air pollution were the power stations, which was pointed out by 8.50% of the respondents. This was mainly a big issue for the respondents' who live in vicinity of the Marsa and Delimara power stations. These respondents also show dissatisfaction in terms of the presence black dust on the building facades and porches. The same respondents also pointed out the severe impacts on health caused by this dust.

Furthermore, it is important to note that in this section, the respondents had to answer this question, otherwise they could not move on to the next question. In view of this, the respondents replied with answers not really relevant to the topic so that they could move on to the following question. This shows that the respondents were at loss in answering this part of the survey and thus, not much accurate results were obtained from this question. As a result, these were classified as "Blank and/or invalid replies".

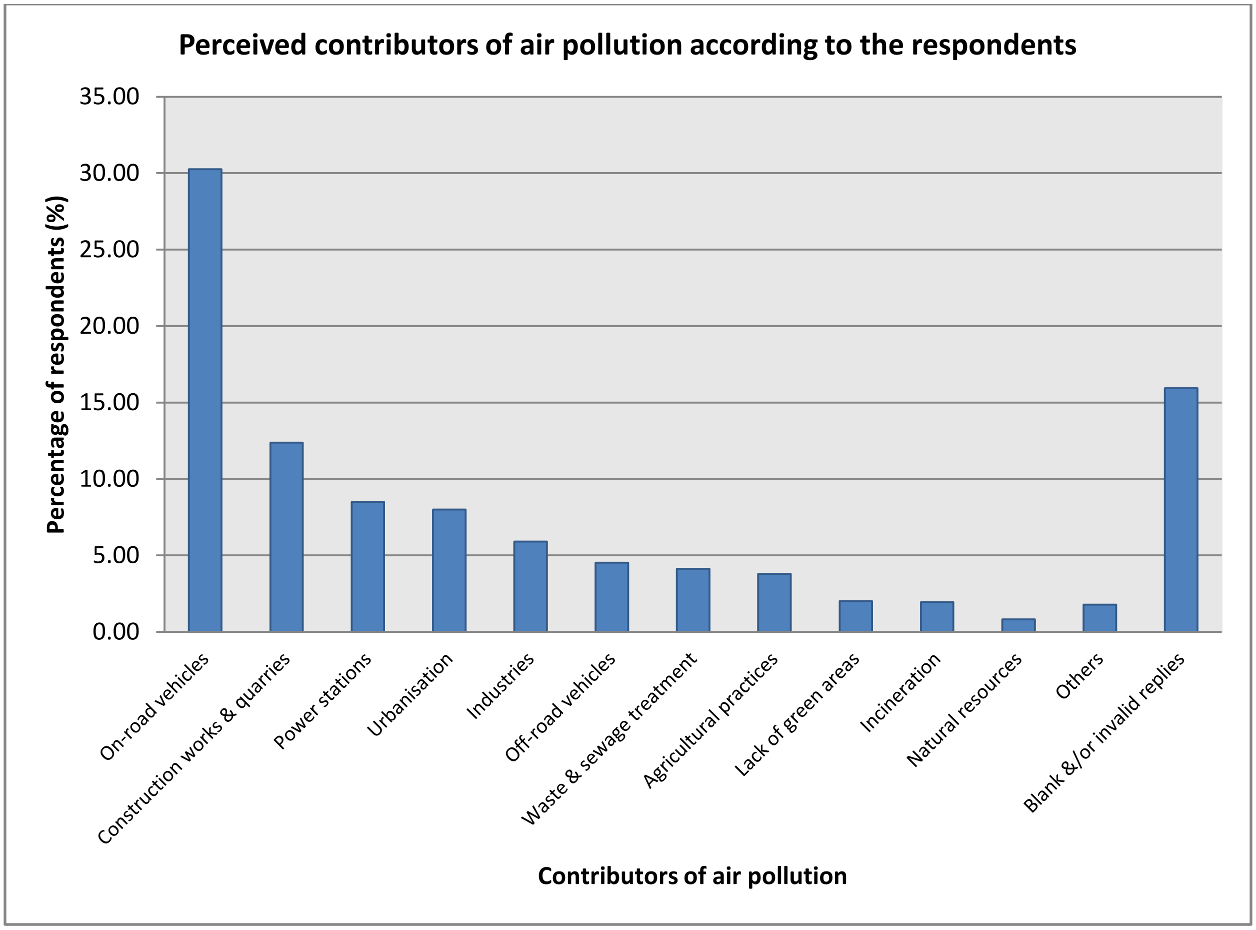

Figure 4.20. - Bar graph showing the perceived contributors of air pollution by the respondents in their localities (Source: Author, 2013).

4.3.10 Socio-demographic analysis of the contributors of air pollution

The relationship between the air pollution contributors and the type of respondents contain both similarities and differences, which are tabulated in Appendix F. This Appendix demonstrates that all respondents of different ages, gender, with different occupation and with different educational background think that on-road vehicular transport, construction works, power stations and urbanisation are large sources of air pollution. If one had to observe the relationship between the sources and the home localities of the respondents, one can note some variability. Indeed, modes of transport seemed to have remained the top contributors in every locality according to most of respondents. Only a few respondents from Kirkop (8.33%) highlighted that on-road vehicles is not an air quality issue in their locality. With regards to construction works, 30.56% and 25% respondents from Siggiewi and Xghajra respectively considers that construction works is the major contributor of air pollution in their locality. In fact, these respondents insisted that construction works contribute to poor air poor air quality more than motorised transport. Moreover, such observation can made:

- industries were reported to be highest by respondents from Marsa and Qormi;
- power stations were reported to be significant air polluters in Marsa (33.33%), Floriana (33.33%) and Marsaxlokk (29.17%); and
- the majority of respondents from Lija (33.33%) and Gzira (26.67%) consider urbanisation be remarkably high in their locality.

4.3.11 Health impacts of air pollution

It can be observed that the most associated health problems perceived by the respondents are asthma and respiratory problems, as per Figure 4.21. This means that a number of people are aware that air pollution causes a lot of damage to the respiratory and pulmonary tract (23.13%). Asthma was the most mentioned one, however other respondents were also aware that air pollution causes other related diseases and problems, such as pneumonia, chronic obstructive pulmonary disease and bronchitis.

Approximately 11.41% of respondents had replied that cancer is another severe health problem associated with poor air quality. In fact, most of these respondents highlighted that the most associated cancer was lung cancer. The respondents seemed to be concerned that associated airborne particles get trapped in the epithelial cells of the lungs and disrupt their genetic material. In addition, some of these respondents also mentioned another type of cancer which can be formed by air pollution and which cancer is leukaemia. In this case, the public perceive that same airborne particles might also form mutations within the genetic material of the blood cells.

Allergies and hay fever also seem to be well known contributors amongst the respondents. In fact, 9.22% of the respondents had highlighted how air pollutants can trigger an allergic inflammation along the epithelial cells lining the respiratory airway.

Furthermore, it is important to point out that most of the answers in this section were irrelevant or invalid. This is because, as in the previous case, respondents had to respond this question, otherwise they could not move on to the following one. Thus, the respondents replied with answers which are inapplicable to the topic so that they could proceed to finish the questionnaire. This also shows that the respondents were at loss in answering this question and thus, not much accurate results were acquired. In view of this, these were also categorised as "Blank and/or invalid replies".

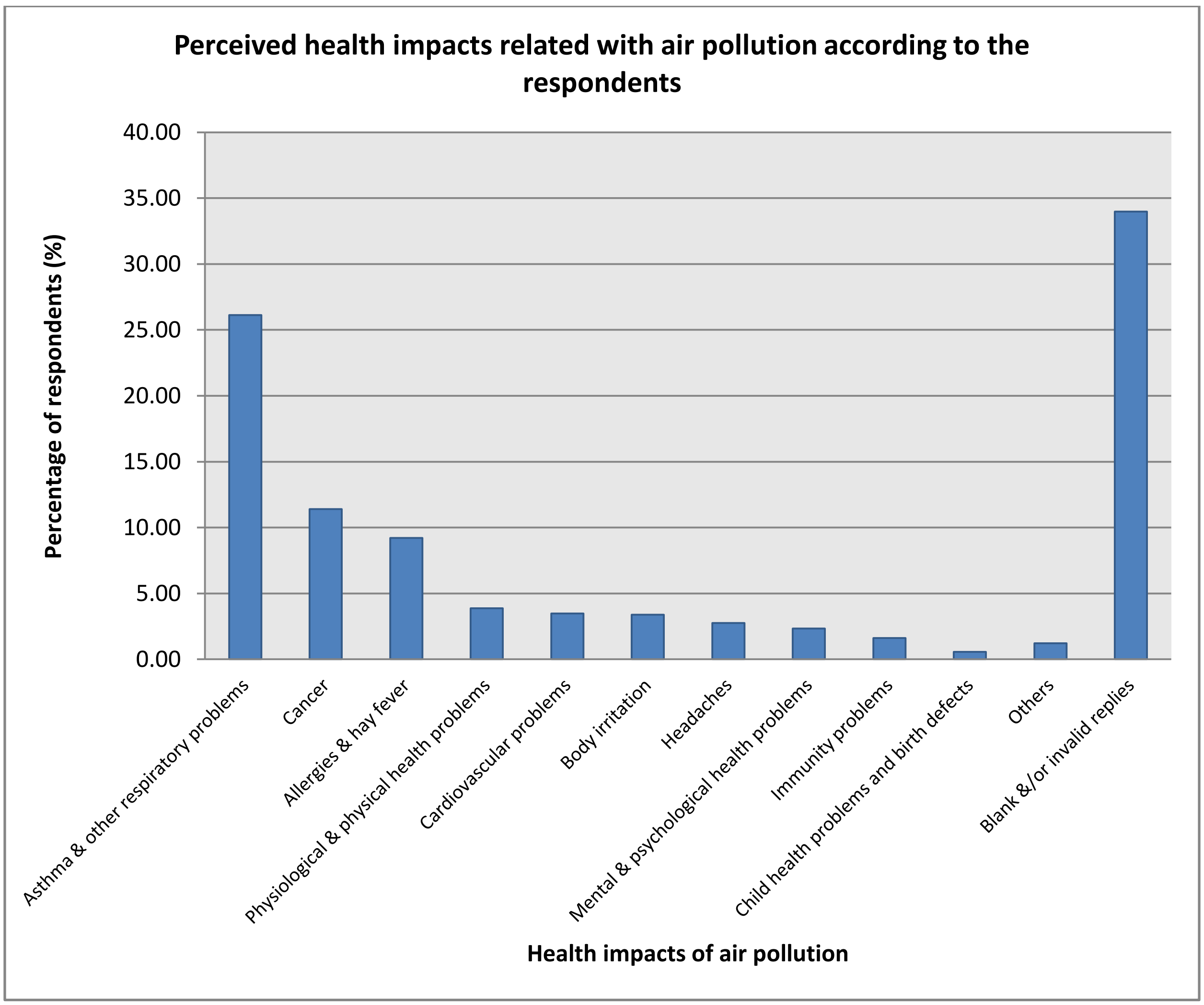

Figure 4.21. - Bar graph showing the perceived health impacts of air pollution by the respondents in their home localities (Source: Author, 2013).

4.3.12 Socio-demographic analysis of the health impacts of air pollution

The results in Appendix G displays the relationship between the health impacts and the socio-demographics of the respondents. The majority of respondents from all groups agree that asthma and related respiratory problems; cancers and hay fevers are an issue in the their home localities. Asthma and pulmonary diseases seem to be perceived as the major concern by a lot of respondents coming from different localities. On the other hand, the following remarks regarding health impacts in different home localities from the collected questionnaires can be made:

- the majority of respondents from Xghajra think that cancer is leading health impact resulting from bad air quality in their locality, accounting to 33.33%;
- 26.67% of the respondents from Paola think that allergies and hay fever are the leading health impacts in their localities; and
- the majority of respondents from Rabat (9.52%) and Gharghur (9.52%) think that heart-related problems are very dominant in their localities.

4.4 Summary and discussion of the data analysis

The results obtained from the analysis of the actual diffusion tube data appear to show a specific spatial distribution trend. The recent readings of benzene levels have shown that they reached their maximum within the localities in the harbour areas. Similarly, nitrogen dioxide levels were observed to have relatively the same spatial distribution pattern. Furthermore, the spatial distribution of both the pollutants seemed to have remained similar between 2005 and 2012, with very minimal changes. These were also proven statistically by means of the one-way ANOVA tests. Furthermore, it can be noted that that throughout the previous decade, there has been a positive relationship between the levels of benzene and nitrogen dioxide, which was proven by Pearson's correlation.

From the questionnaire results, a large number of respondents remarked that the current state of the national air quality is moderate, which was proven by Friedman test. Moreover, there were different opinions with regards the present air quality in the respondents' home localities. However, if one had to notice the answers of these respondents, one would notice that a large number of respondents perceived the localities in the vicinity of the urbanised areas being the most to suffer from a poorer air quality in relation with those in the inland areas. The majority of the same respondents seem to agree that the change in air quality level in Malta over the past three years has been nearly moderate. Also, a lot of these respondents gauged that the state of air quality on localities of the previously mentioned urbanised area of Malta has degenerated over the same time period. In contrast, the respondents said that the inland areas which are furthest away from the urbanised region experienced an improvement in the level of air quality. This was also proven by Friedman test, where the respondents stated that there was an improvement in places such as Mellieha and Rabat, and a shift towards bad air quality in places such Marsa and Paola.

There appears to be a discrepancy between the actual diffusion tube data and the respondents' perceptions from the questionnaire. This was proven by the Pearson's *r* correlation coefficient which correlated the gauge levels assessing both the current and change in state of air quality with each concentrations of benzene and nitrogen dioxide. In all cases, high levels of these air pollutants were found when the gauge scores are low. This negative correlation could have resulted from misconceptions about the air quality in a particular place, which could be derived from a number of secondary sources.

In fact, the major source of information given by the respondents in terms of the current and the change in air quality levels of places was based on their personal observation. This could have happened due to the fact that developing nations, such as Malta, experience large levels of visible and invisible forms of contaminated air quality, which may lead to a "saturation" effect[26] (Saksena, 2007). Since the public is more familar with the visible air pollution, such as traffic exhaust, this may allow it to make intuitive judgements about the air quality of a particular area, which sometimes could be not precise. In view of this situation, the public does not seem to be willing to research scientifical-tested proven data. Therefore, in order to avoid this false misconception, there

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[26] Saksena (2007) refers to the "saturation" effect as being the decrease in the degree of richness/pureness of intensity within a specific medium, which is this case is the air.

is the need for more promotion of education and awareness on the state of air quality and how it is changing, as shall be addressed in the conclusion.

A high percentage of respondents have answered that the air quality in their home locality is largely affected by on-road vehicles. This means that emissions released by motorised vehicles is more of a national problem than a local one. This is in fact highlighted elsewhere by Howel et al. (2003), who state that there are a large number of people who perceive road transport to be the greatest contributor which disintegrates the state of air quality, which could also be the case in this situation. Finally, most of these respondents who emphasised that road transport is an issue also argued that asthma and other related respiratory diseases are associated health problems in their home locality due to poor air quality and this may lead to a national issue.

5 Conclusion and recommendations

Air quality may bring about a number of undesirable results. It is the negative impact that it may have on human beings and their surroundings which raises a high concern on this topic. This chapter shall give a summary on the outcome which was analysed in this research study. To maintain good air quality requires a variety of knowledge. A number of recommendations are to be found hereunder together with further studies related to this research.

5.1 Outcome of this research study

The main objective of this research study was to determine whether there is a relationship between the data gathered from the diffusion tubes and the data collected from the respondents through the use of questionnaires. The following paragraphs will highlight what was established in this research study as follows:

- From the survey, it appears that the respondents perceive that the areas surrounding the harbour are more prone to air pollution and this has increased over the past few years. This perception seems to be in line with the measurements of benzene and nitrogen dioxide readings collected from the diffusion tubes. From these readings in these areas, it can be noted that these measurements were higher than those of inland localities situated in rural settings.

- On the other hand, there seems to be a misconception in terms of the amount of air pollutant level by the respondents. This is due to the fact that these same respondents claim that the air quality around the whole island had relatively deteriorated because of the release of more pollutants in the atmosphere. In comparison, the annual diffusion tubes readings showed that only nitrogen dioxide levels had increased over the past years, whereas benzene had diminished.

- It can be noted that many respondents perceive air quality in a particular place through personal observations and experiences. Also, the majority of the respondent did not quote a concrete source of knowledge and very few referred to national reports.

- A subjective elements can be noted in the questionnaire surveys. A lot of respondents were concerned with air pollution caused by on-road vehicles and its impact on health. In contrast, very few mentioned the severe impacts on vegetation and establishments.

5.2 Recommendations and future studies

As addresses earlier on, it is important that public perception is enhanced through education. This is due to the fact that the public itself has to maintain good air quality. Although the Maltese system follows guidelines both at international and European Union level, the following suggested reforms such as:

- Educating the public to take more active roles in the enhancement of air quality;
- Implementation of strict measures; and
- Implementation of action plans.

All of these recommendations mentioned above prove to a benefit of title, and shall be discussed further on.

5.2.1 Educating the public

"Ignorance of the law excuses no man".

This latin maxim seems to put all the onus on a person who breaks the law, nevertheless although this maxim is used in practice, it is best to create awareness before implementing the law. Public education in terms of air quality is considered to be very useful as everybody may benefit from it.

Awareness on air pollution and on the need to safeguard a high level of air quality could be started at a very young age, possibly at primary level. Here, the pupils would get acquainted with the idea of these type of pollutant gases and their impacts. At a later stage, education should be more at a more scientific level and students should be encouraged to refer to more concrete data from diffusion tubes and reports, and be involved in basic fieldwork studies.

The public at large should be made more aware on how to improve air quality through the media and educational programs which address the subject. To maintain good air quality, interdisciplinary themes should aim on the positive sides of good air quality rather than terrifying the people with the negative impacts.

5.2.2 Implementation of strict measures

In the previous paragraph, education in terms of air quality was advocated. This has to be followed with the implementation of law. In this case, a chance is given to the public to reform itself through knowledge rather than because of disciplinary measures. The next step would be to strengthen the implementation of strict measures. Proper legislation should be construed and a competent authority should make sure that the law is being abided to. Harsh measures should be considered. Nevertheless, one has also not to forget the Polluter Pay Principle. In order to avoid, this situation a person should be considered a recidivist, should he or she break the law a number of times. In this situation, the relapse would bring about greater sanctions.

5.2.3 Implementation of an effective action plan for air quality improvement

An action plan involves a series of procedures and activities which must be taken for a particular strategy to be accomplished. Thus, an action plan is essential for the improvement of air quality in a place like Malta since it can help to regulate and control air pollution around the whole country. In fact, Malta, being an EU member, is obliged to abide by the EU long-term objectives in such a way that by 2020, it needs to cut down atmospheric pollutants, such as benzene and nitrogen dioxide, and stop further increase of tropospheric ozone (Arsić *et al.*, 2011). Therefore, in order for an action plan to achieve its goal to enhance its national state of air quality, it needs to set a number of policy measures to reduce the number of air pollution episodes. Some of these measures could be as follows:

- Reduce air pollutants from traffic emissions

Earlier on, it was discussed that vehicular transport are a major source of hazardous pollutants, which in fact, was pointed out by a number of respondents throughout the conduction of the questionnaire. According to Fenger (2009), there are a number of attempts which can be done to restrict the urban traffic in any country, including Malta. Such examples can include initiatives such as the following:

  - producing more pedestrian zones;
  - restriction of parking places;
  - establishing an efficient public transport to attract more commuters; and
  - encourage and enhance non-polluting means of individual transport.

Furthermore, in order to reduce the amount of contaminants being emitted by motor vehicular transport; companies and universities can adopt a green-travel plan. This is an initiative, whereby people are encouraged to travel by the most sustainable way, generally by avoiding the dependence of their private car. Such possible schemes can be as follows:

  - advocating individuals to either walk or cycle if they are travelling for a short distance; and
  - promoting more the use of public transport and car pooling.

- Upgrading industries with innovative technologies

All the industrial sectors can be encouraged to use the best available technology. These type of technology would be very efficient since it would provide industries with more benefits than costs. In fact, the industrial sectors are known to emit large emissions of gaseous contaminants, especially gases containing volatile organic compounds. Therefore, this issue can contribute in the impact of the national emissions value. Furthermore, government incentives to promote innovative and cleaner technologies could be very suitable for industries.

5.2.4 Future Studies on the transboundary pollution problem

There is a necessity for future researches on the state of air quality, especially related to the transboundary pollution problem. Transboundary problem of air pollutants, namely related to ground ozone is a major problem in Europe, including Malta. Even though tropospheric ozone levels have reduced in Malta (MEPA, 2010b), there is still the need to increase the awareness about it. In addition, this same awareness can lead to a situation where surface ozone concentrations can be diminished by national, regional and international legislation.

Appendix A: Questionnaire

Thesis Questionnaire: Public perception of the state of air quality in Malta

I am Nikolas Cassar, a student who is currently reading for a Masters Degree in Sustainable Environment Resource Management (SERM) through the University of Malta which is also a dual degree in conjunction with James Madison University, Virginia, USA. In partial completion of my dissertation, I am currently conducting a research study to gauge the public's perception on local air quality. It would really be appreciated if you could spare just a few minutes to take part in this study.

No identifiable information will be collected from the participant and no identifiable responses will be presented in the final form of this study. All data collected will be stored in a secure location which will be only accessible by me. All information given will be confidential and all records will be destroyed after the study is completed. Furthermore, I would like to point out that no risks will be imposed from your involvement in this study.

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind. However, once your responses have been submitted and anonymously recorded you will not be able to withdraw from the study.

If you have any questions, concerns or comments during the time of your participation in this study, please do not hesitate to contact me on: ncassar5@gmail.com.

Giving of Consent
I have been given the opportunity to ask questions about this study. I have read this consent and I understand what is being requested of me as a participant in this study. I certify that I am at least 18 years of age. By clicking on "continue", and completing and submitting this anonymous survey, I am consenting to participate in this research.

JAMES MADISON UNIVERSITY.

Continue »

* Required

Section 1

How do you consider the level of air quality in the following places? (Kif tikkonsidra il-livell ta' kwalita' tal-arja fil-postijiet segwenti?) *

Please select one for each place (Jekk jogħġbok, agħżel waħda għal kull post) | NB: 1-Very Poor & 10-Very Good (1-Ħażina Ħafna & 10-Tajba Ħafna)

	1 Very Poor (Ħażina Ħafna)	2	3	4	5	6	7	8	9	10 Very Good (Tajba Ħafna)	Don't Know (Ma Nafx)
Malta											
Home Locality (Lokalita' fejn toqgħod)											
Birkirkara											
Il-Marsa											
Il-Mellieħa											
Il-Mosta											
Ir-Rabat											
Marsaxlokk											
Paola											
Tas-Sliema											
Valletta											

How do you consider the changes on the quality of air in the following places over the past three years? (Kif tikkonsidra l-bidliet fil-kwalita' tal-arja fil-postijiet is-segwenti matul dawn l-aħħar tliet snin?) *

Please select one for each place (Jekk jogħġbok, agħżel waħda għal kull post) | NB: 1-trending towards poorer air quality & 10-trending towards better air quality (1-ixxaqleb lejn kwalita' tal-arja iżjed ħazina & 10-ixxaqleb lejn kwalita' tal-arja iżjed tajba)

	1 Poorer air quality (Kwalita' tal-arja agħar)	2	3	4	5	6	7	8	9	10 Better air quality (Kwalita' tal-arja aħjar)	Don't Know (Ma Nafx)
Malta											
Home Locality (Lokalita' fejn toqgħod)											
Birkirkara											
Il-Marsa											
Il-Mellieħa											
Il-Mosta											
Ir-Rabat											
Marsaxlokk											
Paola											
Tas-Sliema											
Valletta											

From where did you get your information for each of the following places? (Minn fejn ġibt l-informazzjoni għal kull post segwenti?) *

Please select one for each place (Jekk jogħġbok, agħżel waħda għal kull post)

	Personal observation (Osservazzjoni personali)	Media (Mezzi tax-Xandir u Gazzetti)	Education (Edukazzjoni)	Others (Oħrajn)
Malta				
Home Locality (Lokalita' fejn toqgħod)				
Birkirkara				
Il-Marsa				
Il-Mellieħa				
Il-Mosta				
Ir-Rabat				
Marsaxlokk				
Paola				
Tas-Sliema				
Valletta				

If "Others", please specify (Jekk "Oħrajn", jekk jogħġbok speċifika).

* Required

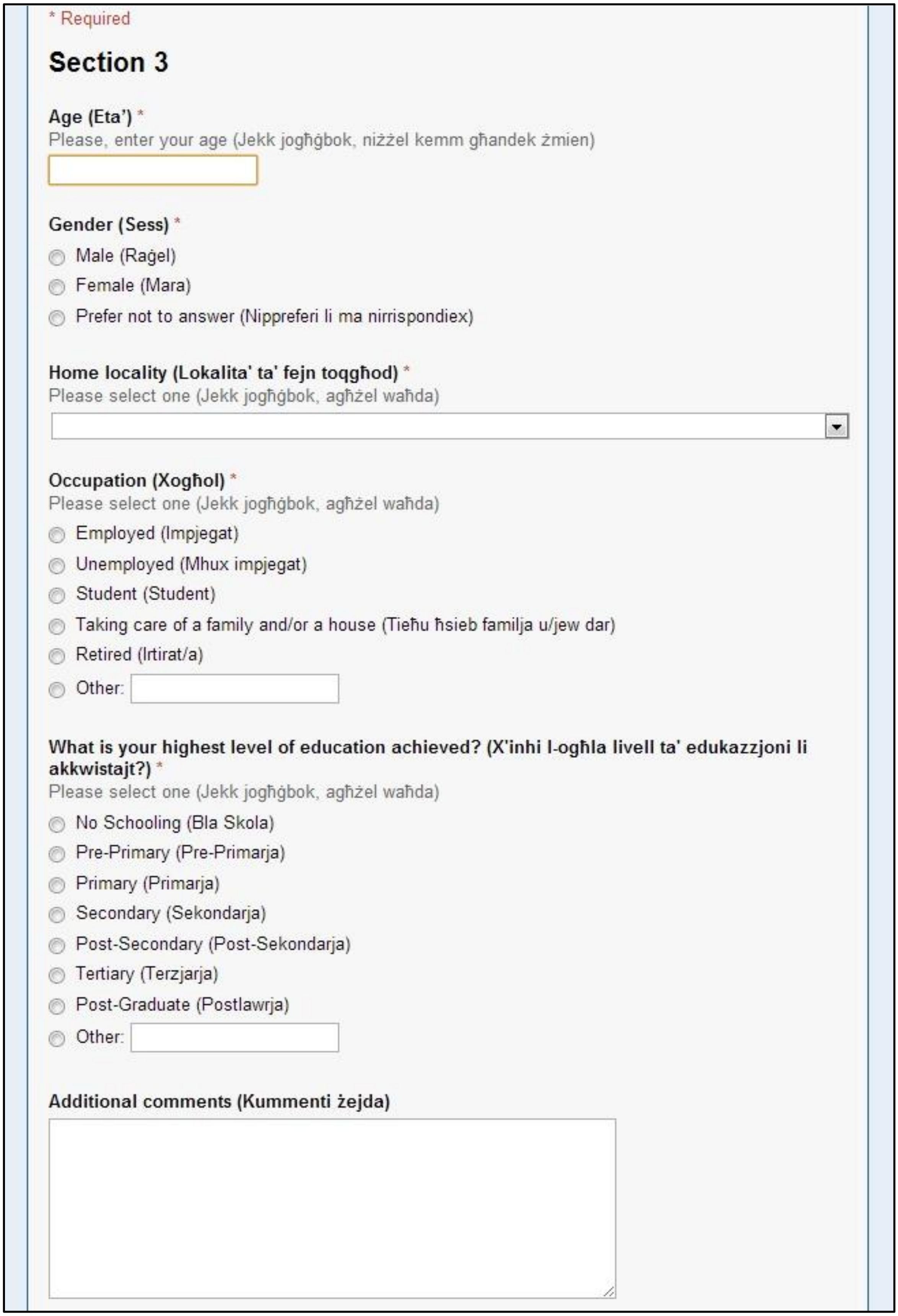
Section 2

In your opinion, which are the top three major contributors of air pollution in your home locality? (Fl-opinjoni tiegħek, liema huma l-iżjed tliet sorsi li jikkontribwixxi għal ħafna tniġġis fl-arja ġol-lokalita' ta' fejn toqgħod?) *

Please, rank your answers by placing 1 as the most and 3 as the minimal contributor of air pollution (Jekk jogħġbok, poġġi dak li tħoss li hu l-iżjed kontributur għat-tniġġis ta' l-arja f'numru 1 u l-inqas f'numru 3)

In your opinion, which are the top three major human health impacts of air pollution in your home locality? (Fl-opinjoni tiegħek, liema huma l-iżjed tliet impatti tas-saħħa tal-bniedem li jirriżultaw minn ħafna tniġġis fl-arja ġol-lokalita' ta' fejn toqgħod?) *

Please, rank your answers by placing 1 as the most and 3 as the minimal human health impact of air pollution (Jekk jogħġbok, poġġi dak li tħoss li hu l-iżjed impatt tas-saħħa tal-bniedem li jirriżulta minn tniġġis ta' l-arja f'numru 1 u l-inqas f'numru 3)



* Required

Section 3

Age (Eta') *

Please, enter your age (Jekk jogħġbok, niżżel kemm għandek żmien)

Gender (Sess) *

- Male (Raġel)
- Female (Mara)
- Prefer not to answer (Nippreferi li ma nirrispondiex)

Home locality (Lokalita' ta' fejn toqgħod) *

Please select one (Jekk jogħġbok, agħżel waħda)

Occupation (Xogħol) *

Please select one (Jekk jogħġbok, agħżel waħda)

- Employed (Impjegat)
- Unemployed (Mhux impjegat)
- Student (Student)
- Taking care of a family and/or a house (Tieħu ħsieb familja u/jew dar)
- Retired (Irtirat/a)
- Other:

What is your highest level of education achieved? (X'inhi l-ogħla livell ta' edukazzjoni li akkwistajt?) *

Please select one (Jekk jogħġbok, agħżel waħda)

- No Schooling (Bla Skola)
- Pre-Primary (Pre-Primarja)
- Primary (Primarja)
- Secondary (Sekondarja)
- Post-Secondary (Post-Sekondarja)
- Tertiary (Terzjarja)
- Post-Graduate (Postlawrja)
- Other:

Additional comments (Kummenti żejda)

Appendix B: Mean annual benzene levels at each diffusion tube (2005-2012)

Locality	Diffusion Tube	X	Y	2005 (μg/m^3)	2006 (μg/m^3)	2007 (μg/m^3)	2008 (μg/m^3)	2009 (μg/m^3)	2010 (μg/m^3)	2011 (μg/m^3)	2012 (μg/m^3)
Attard	ATT 1	449563	3972057	2.61	3.15	2.75	3.50	N/A	2.87	1.24	1.00
Attard	ATT 2	448861	3972298	2.21	2.43	2.04	2.90	N/A	2.60	1.06	0.61
B Bugia	BBG 1	457592	3965380	2.16	2.08	1.73	3.07	N/A	2.49	1.33	0.76
B Bugia	BBG 2	457251	3964658	1.90	2.45	2.35	3.63	N/A	3.03	1.57	1.16
B Bugia	BBG 3	457230	3964142	1.67	1.56	1.20	2.51	N/A	2.53	0.62	0.42
B Kara	BKR 1	451538	3972593	3.71	4.03	3.52	5.51	N/A	5.58	3.74	2.32
B Kara	BKR 2	452464	3972911	2.28	3.09	2.32	3.27	N/A	3.02	1.15	0.97
B Kara	BKR 3	451304	3972385	2.20	2.55	2.19	2.98	N/A	2.73	0.99	0.79
B Kara	BKR 4	453125	3972154	2.56	3.20	2.68	3.56	N/A	2.92	1.50	1.11
Bugibba	BUB 1	444632	3978047	1.64	2.05	1.91	2.38	N/A	2.22	0.80	0.57
Bugibba	BUB 2	446638	3978170	1.98	2.75	2.49	3.00	N/A	2.57	1.23	0.59
Bugibba	BUB 4	447964	3978940	1.80	2.07	1.91	2.33	N/A	2.44	0.79	0.56
Bugibba	BUB 5	447350	3978334	1.77	2.10	2.00	2.43	N/A	2.29	1.06	0.63
Bugibba	BUB 6	448226	3978240	1.59	2.03	1.83	2.34	N/A	2.15	0.66	0.41
Balzan	BZN 1	450591	3972553	2.77	2.90	2.48	3.24	N/A	2.94	1.25	0.97
Balzan	BZN 2	450944	3972829	2.77	3.07	2.76	3.48	N/A	2.91	1.51	1.10
Cospicua	COT 1	456701	3970926	4.07	4.26	3.28	4.78	N/A	4.32	1.60	1.45
Cospicua	COT 2	456995	3971231	3.22	2.42	1.70	3.22	N/A	3.11	1.26	0.74
Cospicua	COT 3	456762	3970526	3.44	3.98	2.65	4.16	N/A	3.79	1.62	0.76
Senglea	COT 4	456545	3971384	3.12	3.37	2.11	3.64	N/A	3.56	1.30	0.91
Dingli	DGL 1	444395	3968783	2.14	2.66	2.49	2.86	N/A	2.65	1.19	0.66
Dingli	DGL 2	444034	3968435	1.14	1.60	1.52	1.97	N/A	1.93	0.61	0.38
Dingli	DGL 3	444181	3968674	1.29	1.52	1.67	2.01	N/A	1.98	0.60	0.41
Floriana	FL 1	455384	3972065	6.85	6.70	6.50	6.06	N/A	5.53	2.20	2.63
Floriana	FL 2	455424	3971790	1.99	1.63	1.67	2.84	N/A	3.11	1.05	0.68
Gudja	GDJ 1	455144	3967517	2.58	2.43	2.10	3.38	N/A	3.16	1.35	1.40
Gudja	GDJ 2	454920	3967269	2.04	1.90	1.67	2.94	N/A	2.90	1.12	0.81
Gudja	GDJ 3	454996	3967201	2.14	1.93	1.80	2.71	N/A	2.62	0.99	0.79
Gzira	GZR 1	454165	3973324	3.27	3.24	3.25	3.09	N/A	2.82	1.73	1.28
Gzira	GZR 2	454127	3973499	3.45	3.91	3.45	3.35	N/A	3.25	1.70	1.54
Gzira	GZR 3	454531	3973821	3.45	4.33	3.26	3.08	N/A	2.77	1.21	1.10

Hamrun	HMR 1	453700	3971516	4.71	4.47	4.12	4.93	N/A	4.57	2.28	2.05
Hamrun	HMR 2	453983	3971447	4.16	5.18	4.68	5.30	N/A	4.90	2.35	2.29
Hamrun	HMR 3	453446	3971836	3.42	3.24	3.03	4.04	N/A	3.88	1.51	1.46
Kordin	KFS	455871	3970810	1.30	1.02	1.09	1.34	N/A	1.17	0.66	0.93
Lija	LJA 1	450405	3973243	2.50	3.30	2.69	3.59	N/A	2.48	0.97	0.67
Lija	LJA 2	449957	3973150	2.20	2.57	2.28	3.15	N/A	2.62	1.32	0.69
Luqa	LQA 1	454046	3968672	3.09	2.78	2.35	3.21	N/A	3.09	1.42	0.91
Luqa	LQA 2	453902	3968737	2.91	2.73	2.45	3.47	N/A	3.05	1.64	0.75
Luqa	LQA 3	453747	3968101	2.24	2.26	2.10	3.57	N/A	2.82	1.57	0.89
Mgarr	MGM 1	443116	3975198	1.45	2.00	1.70	2.36	N/A	2.47	0.68	0.57
Mgarr	MGM 2	442866	3975171	1.27	1.94	1.58	2.03	N/A	2.09	0.71	0.51
Mgarr	MGM 3	442880	3975426	1.36	1.82	1.65	2.01	N/A	1.99	0.82	0.60
Mellieha	MLH 1	442507	3979358	2.94	2.70	2.23	2.69	N/A	2.38	1.50	1.00
Mellieha	MLH 2	442387	3979746	1.63	1.37	1.42	1.85	N/A	1.61	0.93	0.41
Mellieha	MLH 3	442952	3979675	1.41	1.22	1.22	1.78	N/A	2.24	0.82	0.41
Mqabba	MQB 1	452082	3966785	1.39	2.56	1.69	2.57	N/A	2.57	0.76	0.54
Mqabba	MQB 2	451689	3966612	1.29	2.19	1.55	2.49	N/A	2.21	1.01	0.55
Marsa	MRS 1	454523	3970580	2.47	2.28	2.48	3.39	N/A	3.37	1.05	1.05
Marsa	MRS 2	453857	3971007	2.15	2.03	2.26	3.04	N/A	3.19	1.22	0.97
Marsa	MRS 3	454762	3971467	2.13	1.95	1.92	2.97	N/A	2.99	1.28	1.03
Marsa	MRS 4	454382	3971001	2.45	2.33	2.34	3.36	N/A	3.11	1.06	1.20
Msida	MSD 1	454345	3973222	3.95	4.34	3.81	3.10	N/A	3.11	1.83	1.13
Msida	MSD 2	453144	3973159	2.53	2.38	2.05	2.18	N/A	2.23	0.87	0.61
Msida	MSD 3	453969	3972517	3.24	3.60	3.26	3.02	N/A	2.91	1.58	1.15
Marsaskala	MSK 1	460312	3968811	2.64	3.72	2.96	4.03	N/A	2.90	0.66	0.69
Marsaskala	MSK 2	460653	3969223	2.91	2.63	1.16	2.24	N/A	2.38	0.73	0.36
Marsaskala	MSK 3	461279	3968552	2.82	2.07	1.15	2.08	N/A	2.60	1.05	0.37
Mosta	MST 1	448435	3973859	4.65	5.02	4.21	4.19	N/A	3.50	2.01	1.61
Mosta	MST 2	448338	3973621	2.34	2.78	2.83	2.77	N/A	2.52	1.41	0.83
Mosta	MST 3	447218	3974211	1.19	1.63	1.58	2.30	N/A	2.03	0.60	0.56
M Xlokk	MXL 1	458574	3966639	3.12	3.34	2.25	2.89	N/A	2.85	1.24	0.66
M Xlokk	MXL 2	458876	3965960	2.06	2.10	1.54	2.38	N/A	2.56	0.85	0.40
M Xlokk	MXL 3	459238	3966591	1.49	1.41	1.18	2.06	N/A	2.16	0.64	0.42
Naxxar	NXR 1	449519	3975074	1.62	1.67	1.56	2.11	N/A	2.30	0.63	0.39

Naxxar	NXR 2	449784	3974458	1.97	2.18	2.08	2.55	N/A	2.75	0.88	0.54
Naxxar	NXR 3	448572	3974826	1.70	1.88	1.74	2.27	N/A	2.42	0.76	0.46
Paola	PLA 1	455834	3969805	2.91	3.22	1.93	3.10	N/A	3.28	1.12	0.73
Paola	PLA 2	455986	3969954	2.18	2.55	1.70	2.78	N/A	2.76	0.89	0.74
Paola/Tarxien	PLA 3	455705	3969480	3.83	3.89	2.79	3.69	N/A	3.70	1.72	1.64
Paola/Tarxien	PLA 4	455906	3969704	2.89	3.11	2.19	3.22	N/A	3.07	1.21	0.99
Paola/Fgura	PLA 5	456282	3969988	4.68	4.78	3.89	4.77	N/A	4.60	2.06	2.22
Paola/Fgura	PLA 6	456829	3969931	4.28	4.56	3.60	4.60	N/A	4.18	2.31	1.68
Pieta	PT 1	454254	3972132	3.53	3.41	3.35	3.30	N/A	3.31	1.15	1.33
Pieta	PT 2	454535	3971923	2.82	2.54	2.47	3.21	N/A	3.20	1.31	1.00
Pieta	PT 3	454269	3972020	2.85	2.84	2.69	3.17	N/A	3.51	1.44	0.88
Qrendi	QRD 1	451247	3965646	1.17	2.31	1.45	1.68	N/A	2.41	0.78	0.51
Qrendi	QRD 2	450986	3965743	0.99	1.94	1.21	1.58	N/A	2.09	0.70	0.36
Qormi	QRM 1	452845	3970340	3.00	3.71	3.19	3.89	N/A	3.69	2.06	1.40
Qormi	QRM 2	451610	3970472	1.76	2.08	2.03	2.47	N/A	2.45	0.81	0.70
Qormi	QRM 3	451835	3971131	2.23	2.54	2.25	3.12	N/A	2.70	0.90	1.10
Rabat	RBT 1	446018	3971009	3.86	4.46	3.75	4.15	N/A	3.85	2.35	1.89
Rabat	RBT 2	445968	3970428	1.89	2.43	2.20	2.37	N/A	2.63	1.01	0.78
Rabat	RBT 3	445544	3971196	1.69	1.80	1.73	1.88	N/A	2.13	0.71	0.68
Siggiewi	SGG 1	449720	3968485	1.65	2.51	1.75	1.95	N/A	1.87	0.90	0.60
Siggiewi	SGG 2	449414	3967815	1.30	2.29	1.63	1.95	N/A	1.93	0.85	0.68
Siggiewi	SGG 3	448851	3968212	1.31	2.47	1.59	1.96	N/A	2.06	0.90	0.47
San Gwann	SGN 1	452984	3973868	4.19	5.16	4.24	2.86	N/A	2.93	1.34	1.20
San Gwann	SGN 2	452930	3974126	4.37	4.33	3.93	3.75	N/A	3.47	1.71	1.22
San Gwann	SGN 3	452448	3973964	2.59	2.86	2.16	2.16	N/A	2.17	1.00	0.71
Sliema	SLM 1	454992	3974028	4.73	5.20	4.67	4.14	N/A	3.81	1.97	2.24
Sliema	SLM 2	455177	3974559	2.95	3.34	2.65	2.57	N/A	2.75	1.25	1.22
Sliema	SLM 3	454395	3974033	3.84	4.27	4.14	3.87	N/A	3.34	2.19	1.33
Swieqi	SWQ 1	452815	3975618	3.83	2.34	1.90	1.71	N/A	1.97	0.83	0.73
Swieqi	SWQ 2	451,166	3976924	3.14	2.00	1.57	1.49	N/A	1.86	0.68	0.73
Swieqi	SWQ 3	453739	3975348	2.31	2.42	2.11	1.92	N/A	2.64	0.80	0.74
Swieqi	SWQ 4	453957	3975036	4.54	4.39	3.44	2.90	N/A	3.01	1.50	1.07
Swieqi	SWQ 5	453278	3976047	1.87	1.74	1.49	1.46	N/A	1.82	0.50	0.39
Valletta	VLT 1	455770	3972806	2.38	2.26	2.22	2.90	N/A	3.40	1.02	0.94

Valletta	VLT 2	455806	3972623	2.17	1.84	1.69	2.31	N/A	2.50	0.76	0.78
Zebbug	ZBG 1	450124	3970099	2.90	3.54	2.79	2.60	N/A	2.65	1.42	0.90
Zebbug	ZBG 2	449539	3969867	2.88	3.87	2.77	3.01	N/A	2.64	1.30	0.93
Zebbug	ZBG 3	449305	3970477	1.56	2.73	1.74	2.22	N/A	2.09	1.00	0.72
Zabbar	ZBR 1	457837	3970045	3.34	4.36	3.27	4.56	N/A	4.31	2.43	1.96
Zabbar	ZBR 2	458017	3970460	1.90	2.62	1.72	3.20	N/A	3.15	1.10	0.85
Zabbar	ZBR 3	458377	3970702	2.24	2.92	1.92	3.22	N/A	3.28	1.33	1.30
Zurrieq	ZRQ 1	452576	3965730	1.94	2.65	2.06	2.02	N/A	2.53	1.20	0.65
Zurrieq	ZRQ 2	452046	3965165	1.74	2.51	1.87	2.20	N/A	2.33	0.95	0.53
Zurrieq/Safi	ZRQ 3	453412	3965596	1.46	2.42	1.47	2.07	N/A	2.05	0.67	0.48
Zejtun	ZTN 1	457302	3967659	2.93	2.38	2.22	2.99	N/A	2.97	1.45	0.97
Zejtun	ZTN 2	458011	3968124	2.65	2.36	2.24	3.01	N/A	3.08	1.32	0.98
Zejtun	ZTN 3	458431	3967876	2.31	2.21	2.05	2.67	N/A	2.61	1.06	0.72
Zejtun	ZTN 4	458369	3967661	2.63	1.88	1.34	2.52	N/A	2.20	0.74	0.49

Appendix C: Mean annual nitrogen dioxide levels at each diffusion tubes (2005-2012)

Locality	Diffusion Tube	X	Y	2005 ($\mu g/m^3$)	2006 ($\mu g/m^3$)	2007 ($\mu g/m^3$)	2008 ($\mu g/m^3$)	2009 ($\mu g/m^3$)	2010 ($\mu g/m^3$)	2011 ($\mu g/m^3$)	2012 ($\mu g/m^3$)
Attard	ATT 1	449563	3972057	25.21	33.78	34.79	37.90	34.24	31.17	31.31	29.58
Attard	ATT 2	448861	3972298	20.69	22.78	22.38	27.82	21.43	23.85	24.21	24.77
B Bugia	BBG 1	457592	3965380	20.06	24.70	29.78	29.25	27.69	25.47	25.70	26.40
B Bugia	BBG 2	457251	3964658	14.85	22.35	33.64	34.34	27.55	25.36	29.53	30.53
B Bugia	BBG 3	457230	3964142	10.94	12.78	19.28	17.69	14.91	16.41	14.62	17.08
B Kara	BKR 1	451538	3972593	35.53	36.99	43.60	63.39	86.37	83.85	85.57	70.23
B Kara	BKR 2	452464	3972911	20.81	28.43	28.36	31.43	27.70	26.68	26.95	27.07
B Kara	BKR 3	451304	3972385	18.44	24.23	21.74	26.10	22.14	21.61	21.64	21.81
B Kara	BKR 4	453125	3972154	24.72	33.89	34.75	39.49	35.92	36.84	37.07	36.52
Bugibba	BUB 1	444632	3978047	21.48	26.30	31.03	27.74	25.88	24.70	23.66	26.05
Bugibba	BUB 2	446638	3978170	20.69	27.44	27.54	24.86	25.60	24.85	23.08	25.78
Bugibba	BUB 4	447964	3978940	15.27	14.65	16.82	14.81	14.73	14.08	14.31	15.98
Bugibba	BUB 5	447350	3978334	16.10	17.38	22.30	20.26	20.61	20.14	18.16	19.60
Bugibba	BUB 6	448226	3978240	15.35	14.20	14.41	14.44	12.66	12.64	14.11	12.88
Balzan	BZN 1	450591	3972553	26.18	27.32	25.00	33.48	34.30	32.42	31.70	33.91
Balzan	BZN 2	450944	3972829	22.14	28.13	24.96	29.34	26.46	26.91	26.08	23.23
Cospicua	COT 1	456701	3970926	40.38	40.00	49.97	49.66	47.88	42.82	33.79	41.80
Cospicua	COT 2	456995	3971231	28.04	22.95	32.54	30.28	28.84	31.47	28.58	28.01
Cospicua	COT 3	456762	3970526	26.27	29.22	35.30	45.70	45.43	45.00	42.86	42.34
Senglea	COT 4	456545	3971384	29.18	30.52	35.77	36.60	33.97	35.35	30.54	33.34
Dingli	DGL 1	444395	3968783	21.84	20.36	26.79	26.01	25.62	23.19	25.08	21.30
Dingli	DGL 2	444034	3968435	8.65	10.13	9.86	9.27	8.78	7.97	8.92	9.30
Dingli	DGL 3	444181	3968674	9.07	7.39	8.73	10.02	8.10	7.21	7.88	8.30
Floriana	FL 1	455384	3972065	75.91	93.48	81.98	80.37	95.86	77.82	88.75	81.46
Floriana	FL 2	455424	3971790	28.64	41.20	30.62	37.24	46.12	33.42	38.18	28.13
Gudja	GDJ 1	455144	3967517	32.56	37.65	44.36	43.17	42.67	37.92	41.13	43.67
Gudja	GDJ 2	454920	3967269	16.68	19.15	19.88	24.35	18.59	17.87	19.72	19.39
Gudja	GDJ 3	454996	3967201	17.11	21.81	21.59	23.79	21.56	19.21	20.34	21.04
Gzira	GZR 1	454165	3973324	33.76	26.74	40.32	39.29	37.30	39.38	35.66	37.22
Gzira	GZR 2	454127	3973499	34.71	40.91	44.22	46.46	41.16	45.67	46.86	47.24

Gzira	GZR 3	454531	3973821	23.00	27.65	38.67	27.93	26.77	23.95	22.24	23.50
Hamrun	HMR 1	453700	3971516	49.54	54.37	56.39	53.94	56.57	51.66	54.26	55.04
Hamrun	HMR 2	453983	3971447	43.96	53.27	52.65	56.08	56.38	53.91	51.51	53.99
Hamrun	HMR 3	453446	3971836	33.61	32.34	32.89	38.80	36.44	34.18	33.13	30.55
Kordin	KFS	455871	3970810	21.57	21.97	28.44	25.22	27.06	26.59	24.73	23.14
Lija	LJA 1	450405	3973243	28.15	34.17	30.68	32.15	25.66	23.61	23.15	23.55
Lija	LJA 2	449957	3973150	18.82	23.94	21.33	24.67	21.28	23.01	21.80	21.42
Luqa	LQA 1	454046	3968672	34.20	34.63	37.11	38.28	33.52	34.94	37.39	33.11
Luqa	LQA 2	453902	3968737	25.44	26.43	29.91	32.33	30.65	28.33	32.63	25.74
Luqa	LQA 3	453747	3968101	20.35	30.03	31.99	34.36	29.42	26.65	38.87	31.18
Mgarr	MGM 1	443116	3975198	13.89	15.80	15.73	19.34	17.83	22.36	17.39	18.22
Mgarr	MGM 2	442866	3975171	11.56	13.51	15.62	17.64	11.91	12.71	12.83	13.31
Mgarr	MGM 3	442880	3975426	11.57	15.00	15.30	15.43	15.45	15.20	15.14	16.76
Mellieha	MLH 1	442507	3979358	35.91	38.90	42.14	34.85	40.75	39.96	41.82	42.41
Mellieha	MLH 2	442387	3979746	11.32	9.95	9.70	12.54	9.37	9.69	16.13	12.02
Mellieha	MLH 3	442952	3979675	8.84	7.87	8.47	9.62	9.89	11.80	8.18	8.61
Mqabba	MQB 1	452082	3966785	14.26	19.70	28.20	25.06	23.57	24.48	24.63	22.46
Mqabba	MQB 2	451689	3966612	16.59	17.47	22.96	22.31	19.68	19.82	19.13	19.67
Marsa	MRS 1	454523	3970580	34.43	37.80	46.51	44.83	41.83	39.16	35.57	40.77
Marsa	MRS 2	453857	3971007	25.23	29.05	39.20	33.02	31.75	30.94	30.73	29.24
Marsa	MRS 3	454762	3971467	23.89	27.84	32.04	34.81	33.27	34.97	33.61	40.08
Marsa	MRS 4	454382	3971001	26.28	31.42	35.86	37.65	32.49	33.39	33.16	36.05
Msida	MSD 1	454345	3973222	34.45	37.03	43.49	38.16	35.00	35.58	36.22	40.64
Msida	MSD 2	453144	3973159	20.36	22.64	25.92	25.53	23.63	24.81	25.99	27.52
Msida	MSD 3	453969	3972517	27.41	31.60	44.44	44.05	40.26	42.15	41.50	38.14
Marsaskala	MSK 1	460312	3968811	26.94	37.51	43.76	40.41	37.87	23.90	14.70	49.22
Marsaskala	MSK 2	460653	3969223	12.36	17.72	20.43	17.32	16.68	16.99	13.38	13.97
Marsaskala	MSK 3	461279	3968552	15.68	12.55	20.58	14.17	14.13	17.26	29.11	14.27
Mosta	MST 1	448435	3973859	66.28	62.25	61.69	55.82	59.84	55.05	53.15	43.26
Mosta	MST 2	448338	3973621	31.99	33.64	43.25	40.76	40.15	34.19	36.36	35.88
Mosta	MST 3	447218	3974211	11.85	16.50	16.17	17.27	15.11	13.85	14.78	17.57
M Xlokk	MXL 1	458574	3966639	38.43	39.36	38.73	36.11	30.39	30.88	31.28	34.34
M Xlokk	MXL 2	458876	3965960	17.66	23.61	25.79	21.67	22.30	20.81	19.19	21.09
M Xlokk	MXL 3	459238	3966591	10.49	13.07	18.62	16.06	16.07	16.06	14.74	15.08

Naxxar	NXR 1	449519	3975074	10.10	14.75	14.29	17.89	14.17	15.38	14.68	16.42
Naxxar	NXR 2	449784	3974458	21.80	26.26	24.06	28.42	23.04	22.37	21.96	22.78
Naxxar	NXR 3	448572	3974826	11.25	14.50	14.55	17.02	15.39	14.92	15.21	17.09
Paola	PLA 1	455834	3969805	26.25	28.41	31.89	31.03	27.28	28.14	25.64	26.27
Paola	PLA 2	455986	3969954	23.67	22.51	30.64	28.74	25.62	26.61	25.47	24.91
Paola/Tarxien	PLA 3	455705	3969480	33.50	33.11	37.94	34.50	37.23	35.94	34.75	36.27
Paola/Tarxien	PLA 4	455906	3969704	19.80	23.33	29.04	29.15	26.78	26.18	27.41	25.36
Paola/Fgura	PLA 5	456282	3969988	37.24	47.14	55.63	53.00	55.61	53.60	50.50	52.91
Paola/Fgura	PLA 6	456829	3969931	29.84	36.08	43.56	42.97	42.47	39.80	39.58	35.83
Pieta	PT 1	454254	3972132	32.28	36.21	42.33	38.35	36.46	33.75	32.23	32.75
Pieta	PT 2	454535	3971923	30.20	28.94	36.00	36.46	31.79	32.59	30.96	30.92
Pieta	PT 3	454269	3972020	27.37	29.17	31.79	31.25	28.37	29.94	26.43	27.89
Qrendi	QRD 1	451247	3965646	11.36	13.06	16.77	16.63	13.78	13.58	15.66	14.70
Qrendi	QRD 2	450986	3965743	11.04	8.56	9.59	10.69	7.60	7.64	9.48	8.37
Qormi	QRM 1	452845	3970340	37.53	46.47	45.45	52.31	48.93	44.89	49.24	49.43
Qormi	QRM 2	451610	3970472	17.48	23.81	23.97	27.91	24.70	26.27	22.34	23.58
Qormi	QRM 3	451835	3971131	26.06	31.18	29.45	33.54	31.86	30.50	32.77	30.43
Rabat	RBT 1	446018	3971009	38.02	47.23	58.64	56.35	57.11	48.82	48.53	47.18
Rabat	RBT 2	445968	3970428	14.65	20.55	24.93	24.45	23.70	19.42	19.91	19.14
Rabat	RBT 3	445544	3971196	14.13	18.04	13.73	13.07	16.49	11.35	12.20	11.63
Siggiewi	SGG 1	449720	3968485	18.54	23.85	21.27	21.13	17.91	16.05	17.10	16.15
Siggiewi	SGG 2	449414	3967815	10.70	13.21	17.23	16.72	15.56	14.71	14.63	14.53
Siggiewi	SGG 3	448851	3968212	11.31	11.58	14.74	14.91	13.21	13.24	14.33	14.00
San Gwann	SGN 1	452984	3973868	32.87	45.87	53.49	34.49	32.73	34.01	32.76	34.44
San Gwann	SGN 2	452930	3974126	34.00	37.09	43.54	40.55	36.80	33.60	34.03	32.93
San Gwann	SGN 3	452448	3973964	16.14	17.00	20.32	19.96	17.39	17.29	17.10	17.14
Sliema	SLM 1	454992	3974028	44.22	52.16	64.03	54.33	54.20	50.38	49.30	54.65
Sliema	SLM 2	455177	3974559	24.79	27.70	28.43	25.70	24.73	24.42	23.19	26.20
Sliema	SLM 3	454395	3974033	34.73	39.93	59.18	52.47	46.47	51.60	44.86	43.48
Swieqi	SWQ 1	452815	3975618	37.11	20.70	24.78	22.72	19.67	19.22	20.91	29.89
Swieqi	SWQ 2	451,166	3976924	33.31	12.90	15.01	13.14	11.49	13.47	12.35	29.89
Swieqi	SWQ 3	453739	3975348	26.02	27.52	34.36	29.16	27.38	29.99	23.47	26.88
Swieqi	SWQ 4	453957	3975036	42.23	49.13	50.07	48.79	45.53	48.14	45.86	49.70
Swieqi	SWQ 5	453278	3976047	16.82	11.96	13.26	14.56	11.45	12.42	10.96	13.08

Valletta	VLT 1	455770	3972806	25.09	27.79	28.61	32.40	31.94	28.94	32.33	34.41
Valletta	VLT 2	455806	3972623	23.15	26.98	28.53	36.69	25.22	30.20	23.63	23.18
Zebbug	ZBG 1	450124	3970099	36.42	37.61	43.36	38.29	38.89	36.51	36.23	31.08
Zebbug	ZBG 2	449539	3969867	28.37	28.21	32.56	31.02	25.40	25.56	24.88	23.93
Zebbug	ZBG 3	449305	3970477	21.34	23.79	30.60	27.95	26.11	25.56	27.05	25.64
Zabbar	ZBR 1	457837	3970045	32.42	38.62	41.40	41.83	62.40	58.24	51.79	53.03
Zabbar	ZBR 2	458017	3970460	15.73	17.15	20.93	24.57	25.25	19.69	19.35	19.11
Zabbar	ZBR 3	458377	3970702	17.45	20.48	22.27	23.85	22.98	22.19	20.50	18.68
Zurrieq	ZRQ 1	452576	3965730	16.60	21.51	25.70	26.84	24.22	22.80	23.22	26.15
Zurrieq	ZRQ 2	452046	3965165	16.66	22.59	24.65	25.92	20.46	22.03	25.78	24.05
Zurrieq/Safi	ZRQ 3	453412	3965596	11.29	13.91	14.36	18.16	13.74	11.39	11.50	13.74
Zejtun	ZTN 1	457302	3967659	29.16	28.55	38.23	33.86	32.66	32.23	32.60	32.43
Zejtun	ZTN 2	458011	3968124	20.80	25.44	30.56	28.59	27.93	27.12	26.28	26.56
Zejtun	ZTN 3	458431	3967876	20.70	24.06	29.19	25.19	23.61	22.81	21.09	20.59
Zejtun	ZTN 4	458369	3967661	23.55	20.21	22.53	21.46	19.37	17.64	17.17	17.12

Appendix D: Socio-demographic analysis of the current level of air quality in the respondents' home localities

Age Group	**1 (Very Poor)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (Very Good)**	**Don't Know**
18-27	3.85%	8.24%	7.14%	10.44%	13.19%	11.54%	17.58%	16.48%	7.14%	3.85%	0.55%
28-37	10.89%	7.92%	10.89%	12.87%	14.85%	9.90%	14.85%	9.90%	2.97%	4.95%	0.00%
38-47	7.81%	10.94%	12.50%	14.06%	9.38%	7.81%	14.06%	15.63%	6.25%	1.56%	0.00%
48-57	7.14%	0.00%	11.90%	14.29%	16.67%	9.52%	19.05%	4.76%	9.52%	7.14%	0.00%
58-67	10.00%	35.00%	5.00%	10.00%	15.00%	0.00%	10.00%	0.00%	5.00%	10.00%	0.00%
68+	0.00%	0.00%	33.33%	33.33%	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%
Gender	**1 (Very Poor)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (Very Good)**	**Don't Know**
Female	6.36%	8.90%	7.20%	10.59%	13.98%	9.75%	17.37%	13.98%	7.20%	4.66%	0.00%
Male	6.90%	9.20%	12.64%	13.79%	12.64%	9.77%	14.37%	11.49%	4.60%	4.02%	0.57%
Prefer not to answer	50.00%	0.00%	0.00%	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Home Locality	**1 (Very Poor)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (Very Good)**	**Don't Know**
Attard	0.00%	7.14%	7.14%	21.43%	7.14%	21.43%	7.14%	21.43%	7.14%	0.00%	0.00%
Balzan	0.00%	0.00%	0.00%	0.00%	25.00%	0.00%	25.00%	50.00%	0.00%	0.00%	0.00%
Birgu	33.33%	0.00%	0.00%	0.00%	0.00%	66.67%	0.00%	0.00%	0.00%	0.00%	0.00%
Birkirkara	9.52%	9.52%	9.52%	28.57%	14.29%	14.29%	9.52%	4.76%	0.00%	0.00%	0.00%
Birzebbuga	16.67%	0.00%	0.00%	0.00%	33.33%	16.67%	33.33%	0.00%	0.00%	0.00%	0.00%
Bormla	33.33%	33.33%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dingli	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%	33.33%	0.00%	33.33%	0.00%
Fgura	36.36%	27.27%	9.09%	9.09%	0.00%	18.18%	0.00%	0.00%	0.00%	0.00%	0.00%
Floriana	66.67%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Gharghur	0.00%	0.00%	0.00%	14.29%	0.00%	28.57%	0.00%	14.29%	14.29%	28.57%	0.00%
Ghaxaq	20.00%	20.00%	0.00%	0.00%	20.00%	20.00%	20.00%	0.00%	0.00%	0.00%	0.00%
Gudja	0.00%	20.00%	20.00%	0.00%	20.00%	20.00%	20.00%	0.00%	0.00%	0.00%	0.00%

Gzira	0.00%	40.00%	0.00%	40.00%	0.00%	0.00%	20.00%	0.00%	0.00%	0.00%	0.00%
Hamrun	0.00%	16.67%	33.33%	16.67%	0.00%	16.67%	0.00%	0.00%	16.67%	0.00%	0.00%
Iklin	0.00%	0.00%	0.00%	40.00%	0.00%	0.00%	20.00%	20.00%	0.00%	20.00%	0.00%
Isla	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Kalkara	0.00%	0.00%	0.00%	0.00%	50.00%	25.00%	0.00%	25.00%	0.00%	0.00%	0.00%
Kirkop	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%	25.00%	0.00%	25.00%	0.00%
Lija	0.00%	0.00%	0.00%	0.00%	25.00%	0.00%	50.00%	25.00%	0.00%	0.00%	0.00%
Luqa	0.00%	0.00%	0.00%	16.67%	50.00%	16.67%	16.67%	0.00%	0.00%	0.00%	0.00%
Marsa	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Marsaskala	0.00%	9.09%	18.18%	9.09%	9.09%	9.09%	27.27%	9.09%	9.09%	0.00%	0.00%
Marsaxlokk	25.00%	25.00%	25.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mdina	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	33.33%	16.67%	16.67%	33.33%	0.00%
Mellieha	0.00%	22.22%	0.00%	11.11%	0.00%	11.11%	11.11%	33.33%	0.00%	11.11%	0.00%
Mgarr	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%	20.00%	20.00%	40.00%	0.00%
Mosta	0.00%	0.00%	16.67%	11.11%	11.11%	16.67%	27.78%	11.11%	5.56%	0.00%	0.00%
Mqabba	0.00%	0.00%	0.00%	20.00%	40.00%	0.00%	40.00%	0.00%	0.00%	0.00%	0.00%
Msida	16.67%	8.33%	8.33%	25.00%	25.00%	8.33%	8.33%	0.00%	0.00%	0.00%	0.00%
Mtarfa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%	20.00%	60.00%	0.00%
Naxxar	0.00%	0.00%	0.00%	12.50%	0.00%	25.00%	12.50%	37.50%	12.50%	0.00%	0.00%
Paola	40.00%	40.00%	20.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pembroke	0.00%	0.00%	0.00%	33.33%	33.33%	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%
Pieta'	33.33%	0.00%	33.33%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Qormi	0.00%	27.27%	9.09%	18.18%	0.00%	45.45%	0.00%	0.00%	0.00%	0.00%	0.00%
Qrendi	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	25.00%	25.00%	25.00%	25.00%	0.00%
Rabat	0.00%	0.00%	0.00%	0.00%	28.57%	0.00%	28.57%	28.57%	14.29%	0.00%	0.00%
Safi	0.00%	0.00%	25.00%	0.00%	0.00%	0.00%	25.00%	0.00%	50.00%	0.00%	0.00%
San Gwann	9.09%	9.09%	9.09%	9.09%	9.09%	9.09%	18.18%	27.27%	0.00%	0.00%	0.00%
Santa Lucija	0.00%	0.00%	16.67%	0.00%	50.00%	0.00%	16.67%	0.00%	0.00%	16.67%	0.00%
Santa Venera	0.00%	12.50%	37.50%	0.00%	25.00%	12.50%	12.50%	0.00%	0.00%	0.00%	0.00%
Siggiewi	0.00%	0.00%	0.00%	8.33%	8.33%	0.00%	25.00%	25.00%	25.00%	8.33%	0.00%
Sliema	15.38%	30.77%	15.38%	7.69%	0.00%	15.38%	7.69%	0.00%	7.69%	0.00%	0.00%
St. Julian's	7.14%	0.00%	42.86%	28.57%	14.29%	0.00%	7.14%	0.00%	0.00%	0.00%	0.00%

St. Paul's Bay	0.00%	0.00%	0.00%	4.35%	26.09%	4.35%	21.74%	21.74%	17.39%	4.35%	0.00%
Swieqi	0.00%	0.00%	25.00%	16.67%	8.33%	8.33%	16.67%	25.00%	0.00%	0.00%	0.00%
Ta' Xbiex	0.00%	0.00%	25.00%	25.00%	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tarxien	0.00%	37.50%	0.00%	25.00%	12.50%	12.50%	12.50%	0.00%	0.00%	0.00%	0.00%
Valletta	33.33%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%
Xghajra	0.00%	0.00%	0.00%	50.00%	25.00%	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%
Zabbar	0.00%	0.00%	15.38%	7.69%	30.77%	0.00%	15.38%	7.69%	15.38%	0.00%	7.69%
Zebbug	0.00%	0.00%	0.00%	0.00%	11.11%	0.00%	66.67%	22.22%	0.00%	0.00%	0.00%
Zejtun	0.00%	0.00%	0.00%	14.29%	28.57%	14.29%	28.57%	14.29%	0.00%	0.00%	0.00%
Zurrieq	0.00%	6.67%	0.00%	0.00%	6.67%	6.67%	20.00%	46.67%	13.33%	0.00%	0.00%
Occupation	**1 (Very Poor)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (Very Good)**	**Don't Know**
Employed	6.28%	7.11%	9.62%	14.64%	12.13%	10.46%	18.41%	12.55%	5.02%	3.35%	0.42%
Retired	6.67%	26.67%	6.67%	13.33%	20.00%	0.00%	0.00%	6.67%	6.67%	13.33%	0.00%
Self-employed	6.67%	13.33%	13.33%	6.67%	20.00%	0.00%	33.33%	6.67%	0.00%	0.00%	0.00%
Student	6.25%	8.33%	8.33%	10.42%	11.46%	12.50%	12.50%	15.63%	9.38%	5.21%	0.00%
Taking care of a family and/or a house	11.43%	14.29%	8.57%	5.71%	14.29%	5.71%	5.71%	17.14%	8.57%	8.57%	0.00%
Unemployed	8.33%	8.33%	16.67%	0.00%	33.33%	8.33%	25.00%	0.00%	0.00%	0.00%	0.00%
Level of education	**1 (Very Poor)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (Very Good)**	**Don't Know**
Others	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Post-Graduate	5.60%	8.80%	8.80%	12.80%	11.20%	12.00%	15.20%	13.60%	7.20%	4.00%	0.80%
Post-Secondary	6.10%	12.20%	12.20%	12.20%	12.20%	9.76%	15.85%	12.20%	2.44%	4.88%	0.00%
Primary	0.00%	0.005	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Secondary	15.91%	18.18%	9.09%	6.82%	13.64%	4.55%	13.64%	6.82%	6.82%	4.55%	0.00%
Tertiary	5.66%	5.03%	8.81%	13.21%	14.47%	9.43%	17.61%	14.47%	6.92%	4.40%	0.00%

Appendix E: Socio-demographic analysis of the change in level of air quality in the respondents' home localities

Age Group	**1 (Very Bad)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (Very Good)**	**Don't Know**
18-27	9.89%	4.95%	6.59%	15.93	28.02%	7.14%	7.14%	6.04%	1.65%	2.20%	10.44%
28-37	8.91%	13.86%	11.88%	13.86%	22.77%	8.91%	3.96%	4.95%	2.97%	2.97%	4.95%
38-47	14.06%	7.81%	17.19%	10.94%	18.75%	7.81%	12.50%	1.56%	1.56%	1.56%	6.25%
48-57	11.90%	7.14%	9.52%	14.29%	28.57%	9.52%	9.52%	0.00%	0.00%	2.38%	7.14%
58-67	20.00%	20.00%	10.00%	5.00%	20.00%	10.00%	0.00%	5.00%	5.00%	0.00%	5.00%
68+	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	33.33%	33.33%	0.00%	0.00%	0.00%
Gender	**1 (Very Bad)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (Very Good)**	**Don't Know**
Female	11.02%	7.20%	10.17%	12.71%	25.85%	8.90%	7.20%	3.39%	2.97%	1.69%	8.90%
Male	10.34%	10.34%	9.77%	15.52%	23.56%	6.90%	7.47%	6.32%	0.57%	2.87%	6.32%
Prefer not to answer	50.00%	0.00%	0.00%	0.00%	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Home Locality	**1 (Very Bad)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (Very Good)**	**Don't Know**
Attard	7.14%	14.29%	7.14%	14.29%	35.71%	0.00%	7.14%	0.00%	0.00%	0.00%	14.29%
Balzan	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%	25.00%	0.00%	0.00%	0.00%
Birgu	33.33%	0.00%	0.00%	0.00%	33.33%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%
Birkirkara	14.29%	14.29%	0.00%	14.29%	38.10%	0.00%	9.52%	0.00%	0.00%	0.00%	9.52%
Birzebbuga	0.00%	16.67%	16.67%	16.67%	16.67%	0.00%	0.00%	16.67%	16.67%	0.00%	0.00%
Bormla	66.67%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dingli	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	33.33%
Fgura	36.36%	27.27%	9.09%	0.00%	18.18%	9.09%	0.00%	0.00%	0.00%	0.00%	0.00%
Floriana	66.67%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Gharghur	0.00%	0.00%	28.57%	14.29%	0.00%	0.00%	28.57%	0.00%	0.00%	14.29%	14.29%
Ghaxaq	20.00%	20.00%	0.00%	0.00%	40.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%
Gudja	20.00%	20.00%	0.00%	20.00%	40.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Gzira	20.00%	0.00%	60.00%	0.00%	0.00%	0.00%	20.00%	0.00%	0.00%	0.00%	0.00%
Hamrun	33.33%	0.00%	0.00%	16.67%	16.67%	16.67%	0.00%	0.00%	0.00%	16.67%	0.00%
Iklin	0.00%	0.00%	20.00%	0.00%	20.00%	0.00%	20.00%	0.00%	0.00%	0.00%	40.00%
Isla	33.33%	66.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Kalkara	0.00%	0.00%	25.00%	0.00%	25.00%	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Kirkop	0.00%	0.00%	0.00%	0.00%	50.00%	25.00%	25.00%	0.00%	0.00%	0.00%	0.00%
Lija	0.00%	0.00%	0.00%	25.00%	50.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Luqa	0.00%	16.67%	16.67%	16.67%	16.67%	16.67%	0.00%	0.00%	0.00%	0.00%	16.67%
Marsa	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Marsaskala	0.00%	18.18%	9.09%	27.27%	18.18%	18.18%	9.09%	0.00%	0.00%	0.00%	0.00%
Marsaxlokk	25.00%	37.50%	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	12.50%	0.00%
Mdina	0.00%	0.00%	0.00%	0.00%	16.67%	16.67%	0.00%	33.33%	0.00%	0.00%	33.33%
Mellieha	0.00%	0.00%	11.11%	22.22%	22.22%	11.11%	0.00%	0.00%	0.00%	11.11%	22.22%
Mgarr	0.00%	0.00%	0.00%	0.00%	20.00%	0.00%	0.00%	40.00%	0.00%	40.00%	0.00%
Mosta	0.00%	0.00%	16.67%	22.22%	27.78%	5.56%	5.56%	11.11%	0.00%	0.00%	11.11%
Mqabba	0.00%	0.00%	20.00%	0.00%	60.00%	20.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Msida	8.33%	8.33%	16.67%	25.00%	41.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mtarfa	0.00%	0.00%	0.00%	0.00%	20.00%	0.00%	0.00%	20.00%	0.00%	20.00%	40.00%
Naxxar	0.00%	0.00%	0.00%	25.00%	37.50%	0.00%	0.00%	12.50%	0.00%	0.00%	25.00%
Paola	40.00%	20.00%	0.00%	0.00%	40.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pembroke	0.00%	0.00%	0.00%	66.67%	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%
Pieta'	33.33%	0.00%	33.33%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Qormi	0.00%	18.18%	9.09%	27.27%	27.27%	18.18%	0.00%	0.00%	0.00%	0.00%	0.00%
Qrendi	0.00%	0.00%	0.00%	0.00%	50.00%	25.00%	25.00%	0.00%	0.00%	0.00%	0.00%
Rabat	0.00%	0.00%	0.00%	42.86%	57.14%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Safi	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%	25.00%	25.00%	25.00%	0.00%	0.00%
San Gwann	0.00%	18.18%	18.18%	9.09%	18.18%	9.09%	18.18%	0.00%	0.00%	0.00%	9.09%
Santa Lucija	16.67%	0.00%	0.00%	0.00%	33.33%	16.67%	16.67%	0.00%	0.00%	0.00%	16.67%
Santa Venera	0.00%	25.00%	12.50%	37.50%	12.50%	0.00%	0.00%	0.00%	0.00%	0.00%	12.50%
Siggiewi	0.00%	8.33%	0.00%	0.00%	8.33%	8.33%	33.33%	0.00%	16.67%	8.33%	16.67%
Sliema	23.08%	7.69%	23.08%	15.38%	15.38%	7.69%	0.00%	7.69%	0.00%	0.00%	0.00%
St. Julian's	14.29%	7.14%	14.29%	42.86%	7.14%	7.14%	7.14%	0.00%	0.00%	0.00%	0.00%

St. Paul's Bay	8.70%	0.00%	17.39%	13.04%	8.70%	17.39%	17.39%	8.70%	4.35%	0.00%	4.35%
Swieqi	0.00%	16.67%	16.67%	0.00%	33.33%	8.33%	0.00%	8.33%	0.00%	0.00%	16.67%
Ta' Xbiex	0.00%	0.00%	25.00%	50.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tarxien	25.00%	0.00%	12.50%	0.00%	62.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Valletta	66.67%	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%
Xghajra	0.00%	0.00%	25.00%	0.00%	75.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Zabbar	0.00%	7.69%	7.69%	15.38%	23.08%	7.69%	7.69%	0.00%	7.69%	7.69%	15.38%
Zebbug	11.11%	0.00%	0.00%	22.22%	22.22%	11.11%	22.22%	11.11%	0.00%	0.00%	0.00%
Zejtun	0.00%	0.00%	14.29%	14.29%	57.14%	0.00%	0.00%	0.00%	0.00%	0.00%	14.29%
Zurrieq	6.67%	0.00%	0.00%	0.00%	40.00%	20.00%	6.67%	13.33%	6.67%	0.00%	6.67%
Occupation	**1 (Very Bad)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (Very Good)**	**Don't Know**
Employed	8.79%	7.53%	11.72%	16.74%	23.43%	6.69%	8.37%	5.44%	2.51%	2.93	5.86
Retired	20.00%	0.00%	6.67%	6.67%	26.67%	0.00%	6.67%	13.33%	6.67%	0.00	13.33
Self-employed	20.00%	13.33%	13.33%	26.67%	6.67%	6.67%	13.33%	0.00%	0.00%	0.00	0.00
Student	8.33%	7.29%	6.25%	11.46%	32.29%	10.42%	3.13%	4.17%	1.04%	2.08	13.54
Taking care of a family and/or a house	22.86%	17.14%	11.43%	0.00%	22.86%	11.43%	8.57%	0.00%	0.00%	0.00	5.71
Unemployed	16.675	16.67%	0.00%	8.33%	25.00%	16.67%	8.33%	0.00%	0.00%	0.00	8.33
Level of education	**1 (Very Bad)**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (Very Good)**	**Don't Know**
Others	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Post-Graduate	10.40%	8.00%	8.00%	18.40%	24.00%	6.40%	7.20%	4.00%	3.20%	4.00%	6.40%
Post-Secondary	8.54%	10.98%	8.54%	17.07%	25.61%	4.88%	8.54%	0.00%	0.00%	2.44%	13.41%
Primary	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Secondary	29.55%	9.09%	9.09%	6.82%	22.73%	4.55%	6.82%	9.09%	2.27%	0.00%	0.00%
Tertiary	7.55%	7.55%	12.58%	10.69%	25.79%	11.32%	6.92%	6.29%	1.89%	1.26%	8.18%

Appendix F: Socio-demographic analysis of the contributors of air pollution

Age Group	On-road vehicles	Construction works & quarries (%)	Off-road vehicles	Industries	Power stations	Urbanisation	Waste & sewage treatment	Agricultural	Lack of green areas	Incineration	Natural resources	Others	Blank &/or invalid replies
18-27	31.32%	8.79%	3.48%	6.59%	7.88%	8.79%	3.11%	2.38%	2.01%	2.38%	1.10%	1.65%	20.51%
28-37	29.70%	13.20%	4.62%	7.26%	9.57%	4.62%	6.60%	4.62%	1.98%	2.97%	0.66%	2.64%	11.55%
38-47	28.65%	14.58%	5.73%	3.65%	9.38%	10.42%	3.13%	3.65%	1.56%	0.52%	0.52%	1.56%	16.67%
48-57	28.57%	17.46%	4.76%	4.76%	7.94%	9.52%	4.76%	7.14%	2.38%	0.00%	0.00%	1.59%	11.11%
58-67	31.67%	21.67%	8.33%	3.33%	8.33%	8.33%	3.33%	5.00%	3.33%	1.67%	1.67%	0.00%	3.33%
68+	33.33%	22.22%	11.11%	0.00%	0.00%	0.00%	0.00%	11.11%	0.00%	0.00%	0.00%	0.00%	22.22%

Gender	On-road vehicles	Construction works & quarries	Off-road vehicles	Industries	Power stations	Urbanisation	Waste & sewage treatment	Agricultural	Lack of green areas	Incineration	Natural resources	Others	Blank &/or invalid replies
Female	29.80%	11.72%	4.66%	6.50%	7.77%	8.19%	4.24%	4.10%	1.69%	1.41%	1.27%	1.69%	16.95%
Male	30.84%	13.22%	4.41%	4.98%	9.39%	7.85%	4.02%	3.45%	2.49%	2.68%	0.19%	1.92%	14.56%
Prefer not to answer	33.33%	16.67%	0.00%	16.67%	16.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.67%

Home Locality	On-road vehicles	Construction works & quarries	Off-road vehicles	Industries	Power stations	Urbanisation	Waste & sewage treatment	Agricultural	Lack of green areas	Incineration	Natural resources	Others	Blank &/or invalid replies
Attard	30.95%	16.67%	0.00%	0.00%	0.00%	11.90%	4.76%	7.14%	2.38%	2.38%	0.00%	2.38%	21.43%
Balzan	33.33%	33.33%	0.00%	25.00%	8.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Birgu	33.33%	11.11%	22.22%	11.11%	22.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Birkirkara	31.75%	6.35%	1.59%	12.70%	11.11%	7.94%	1.59%	1.59%	3.17%	3.17%	1.59%	1.59%	15.87%
Birzebbuga	16.67%	0.00%	27.78%	0.00%	33.33%	0.00%	0.00%	5.56%	0.00%	0.00%	0.00%	0.00%	16.67%
Bormla	22.22%	33.33%	22.22%	0.00%	11.11%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dingli	33.33%	22.22%	0.00%	0.00%	0.00%	11.11%	0.00%	11.11%	0.00%	0.00%	0.00%	0.00%	22.22%
Fgura	33.33%	0.00%	3.03%	0.00%	24.24%	3.03%	9.09%	0.00%	6.06%	0.00%	0.00%	0.00%	21.21%
Floriana	33.33%	11.11%	11.11%	0.00%	33.33%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Gharghur	33.33%	19.05%	0.00%	0.00%	4.76%	4.76%	9.52%	4.76%	0.00%	4.76%	0.00%	0.00%	19.05%
Ghaxaq	33.33%	33.33%	6.67%	0.00%	6.67%	6.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.33%
Gudja	33.33%	0.00%	20.00%	0.00%	13.33%	6.67%	0.00%	0.00%	0.00%	6.67%	0.00%	6.67%	13.33%
Gzira	33.33%	6.67%	6.67%	0.00%	6.67%	26.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%
Hamrun	33.33%	11.11%	5.56%	5.56%	16.67%	11.11%	0.00%	5.56%	0.00%	5.56%	0.00%	0.00%	5.56%
Iklin	33.33%	0.00%	0.00%	20.00%	6.67%	6.67%	13.33%	0.00%	0.00%	6.67%	0.00%	0.00%	13.33%
Isla	33.33%	22.22%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.11%
Kalkara	33.33%	16.67%	8.33%	8.33%	8.33%	0.00%	8.33%	8.33%	0.00%	0.00%	0.00%	0.00%	8.33%
Kirkop	8.33%	16.67%	16.67%	8.33%	16.67%	8.33%	0.00%	16.67%	0.00%	0.00%	0.00%	0.00%	8.33%
Lija	25.00%	16.67%	0.00%	8.33%	0.00%	33.33%	0.00%	8.33%	0.00%	0.00%	0.00%	0.00%	8.33%
Luqa	33.33%	0.00%	11.11%	16.67%	11.11%	11.11%	5.56%	5.56%	0.00%	0.00%	0.00%	0.00%	5.56%
Marsa	33.33%	0.00%	0.00%	33.33%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Marsaskala	24.24%	9.09%	3.03%	3.03%	18.18%	0.00%	15.15%	0.00%	0.00%	6.06%	6.06%	0.00%	15.15%
Marsaxlokk	20.83%	4.17%	16.67%	4.17%	29.17%	0.00%	0.00%	0.00%	0.00%	8.33%	0.00%	0.00%	16.67%
Mdina	33.33%	5.56%	0.00%	0.00%	0.00%	0.00%	11.11%	16.67%	0.00%	0.00%	0.00%	0.00%	33.33%
Mellieha	33.33%	18.52%	7.41%	7.41%	3.70%	11.11%	0.00%	3.70%	0.00%	0.00%	0.00%	0.00%	14.81%
Mgarr	26.67%	20.00%	0.00%	0.00%	0.00%	0.00%	0.00%	26.67%	0.00%	6.67%	0.00%	0.00%	20.00%
Mosta	33.33%	9.26%	1.85%	14.81%	5.56%	1.85%	3.70%	5.56%	3.70%	0.00%	3.70%	0.00%	16.67%
Mqabba	26.67%	33.33%	13.33%	13.33%	0.00%	6.67%	0.00%	6.67%	0.00%	0.00%	0.00%	0.00%	0.00%
Msida	33.33%	2.78%	2.78%	0.00%	2.78%	11.11%	0.00%	2.78%	5.56%	5.56%	2.78%	5.56%	25.00%
Mtarfa	26.67%	26.67%	0.00%	0.00%	0.00%	20.00%	0.00%	6.67%	0.00%	0.00%	0.00%	6.67%	13.33%
Naxxar	25.00%	12.50%	0.00%	0.00%	0.00%	20.83%	4.17%	0.00%	0.00%	4.17%	0.00%	4.17%	29.17%
Paola	26.67%	6.67%	6.67%	6.67%	26.67%	0.00%	0.00%	0.00%	6.67%	0.00%	0.00%	0.00%	20.00%
Pembroke	33.33%	11.11%	0.00%	0.00%	0.00%	22.22%	22.22%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%
Pieta'	33.33%	0.00%	11.11%	0.00%	22.22%	11.11%	0.00%	0.00%	11.11 %	0.00%	0.00%	0.00%	11.11%
Qormi	30.30%	12.12%	0.00%	15.15%	12.12%	15.15%	0.00%	3.03%	6.06%	0.00%	0.00%	0.00%	6.06%
Qrendi	25.00%	25.00%	0.00%	8.33%	8.33%	8.33%	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rabat	33.33%	9.52%	0.00%	0.00%	0.00%	14.29%	0.00%	9.52%	0.00%	9.52%	0.00%	9.52%	14.29%
Safi	33.33%	8.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.33%	0.00%	0.00%	0.00%	50.00%
San Gwann	33.33%	6.06%	0.00%	12.12%	12.12%	3.03%	0.00%	3.03%	0.00%	3.03%	3.03%	3.03%	21.21%
Santa Lucija	27.78%	16.67%	5.56%	5.56%	22.22%	5.56%	0.00%	0.00%	0.00%	0.00%	5.56%	0.00%	11.11%
Santa Venera	33.33%	12.50%	4.17%	12.50%	0.00%	20.83%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.67%
Siggiewi	27.78%	30.56%	0.00%	5.56%	0.00%	8.33%	0.00%	11.11%	0.00%	0.00%	0.00%	2.78%	13.89%

Sliema	33.33%	15.38%	0.00%	5.13%	2.56%	10.26%	5.13%	0.00%	2.56%	2.56%	2.56%	0.00%	20.51%
St. Julian's	33.33%	11.90%	2.38%	2.38%	2.38%	4.76%	9.52%	4.76%	2.38%	0.00%	0.00%	4.76%	21.43%
St. Paul's Bay	27.54%	8.70%	5.80%	4.35%	1.45%	8.70%	13.04%	1.45%	4.35%	0.00%	1.45%	5.80%	17.39%
Swieqi	33.33%	27.78%	0.00%	0.00%	0.00%	16.67%	0.00%	0.00%	2.78%	0.00%	0.00%	0.00%	19.44%
Ta' Xbiex	33.33%	8.33%	16.67%	0.00%	8.33%	8.33%	0.00%	0.00%	0.00%	16.67%	0.00%	0.00%	8.33%
Tarxien	29.17%	4.17%	0.00%	8.33%	20.83%	8.33%	4.17%	0.00%	4.17%	0.00%	0.00%	4.17%	16.67%
Valletta	22.22%	11.11%	22.22%	0.00%	11.11%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	22.22%
Xghajra	16.67%	25.00%	25.00%	0.00%	8.33%	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Zabbar	28.21%	7.69%	5.13%	12.82%	10.26%	2.56%	10.26%	2.56%	2.56%	2.56%	0.00%	0.00%	15.38%
Zebbug	29.63%	14.81%	3.70%	0.00%	0.00%	18.52%	0.00%	3.70%	3.70%	0.00%	0.00%	0.00%	25.93%
Zejtun	33.33%	9.52%	0.00%	14.29%	23.81%	0.00%	4.76%	0.00%	4.76%	0.00%	0.00%	0.00%	9.52%
Zurrieq	33.33%	15.56%	0.00%	0.00%	4.44%	2.22%	6.67%	6.67%	2.22%	4.44%	0.00%	8.89%	15.56%

Occupation	**On-road vehicles**	**Construction works & quarries**	**Off-road vehicles**	**Industries**	**Power stations**	**Urbanisation**	**Waste & sewage treatment**	**Agricultural**	**Lack of green areas**	**Incineration**	**Natural resources**	**Others**	**Blank &/or invalid replies**
Employed	29.57%	12.83%	4.60%	5.58%	9.34%	6.97%	3.49%	3.77%	2.23%	2.37%	0.56%	1.53%	17.15%
Retired	31.11%	20.00%	8.89%	2.22%	4.44%	6.67%	4.44%	6.67%	2.22%	0.00%	2.22%	0.00%	11.11%
Self-employed	31.11%	17.78%	4.44%	2.22%	4.44%	15.56%	0.00%	0.00%	2.22%	0.00%	2.22%	6.67%	13.33%
Student	31.94%	8.33%	2.78%	6.94%	8.33%	9.38%	5.56%	3.47%	1.04%	2.08%	0.69%	2.08%	17.36%
Taking care of a family and/or a house	29.52%	17.14%	7.62%	7.62%	7.62%	9.52%	5.71%	5.71%	1.90%	0.00%	0.00%	0.00%	7.62%
Unemployed	30.56%	5.56%	2.78%	8.33%	5.56%	5.56%	5.56%	2.78%	5.56%	2.78%	5.56%	5.56%	13.89%

Level of education	**On-road vehicles**	**Construction works & quarries**	**Off-road vehicles**	**Industries**	**Power stations**	**Urbanisation**	**Waste & sewage treatment**	**Agricultural**	**Lack of green areas**	**Incineration**	**Natural resources**	**Others**	**Blank &/or invalid replies**
Others	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%	33.33%	33.33%	0.00%
Post-Graduate	30.93%	10.67%	4.00%	6.13%	9.33%	8.00%	4.27%	4.27%	1.60%	2.13%	0.80%	1.87%	16.00%
Post-Secondary	30.89%	12.20%	4.07%	6.91%	6.50%	9.35%	4.07%	2.85%	2.85%	2.44%	0.81%	0.81%	16.26%
Primary	33.33%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	33.33%
Secondary	31.06%	15.15%	8.33%	4.55%	8.33%	8.33%	4.55%	4.55%	1.52%	1.52%	0.00%	0.76%	11.36%
Tertiary	29.35%	13.21%	4.19%	5.45%	9.01%	7.34%	3.77%	3.77%	2.10%	1.68%	0.84%	2.31%	16.98%

Appendix G: Socio-demographic analysis of health impacts of air pollution

Age Group	Asthma & other respiratory problems	Cancer	Allergies & hay fever	Body irritation	Child health problems and birth defects	Physiological & physical health problems	Cardiovascular problems	Headaches	Mental & psychological health problems	Immunity problems	Others	Blank and/or invalid replies
18-27	27.29%	11.72%	6.59%	2.75%	0.37%	4.03%	3.30%	1.47%	3.48%	1.28%	1.10%	36.63%
28-37	25.41%	10.23%	10.23%	2.31%	0.99%	2.97%	3.63%	3.63%	1.98%	1.98%	0.66%	35.97%
38-47	27.08%	10.94%	13.02%	5.21%	1.04%	5.21%	2.60%	4.17%	0.00%	2.08%	2.08%	26.56%
48-57	19.84%	11.90%	8.73%	5.56%	0.00%	3.17%	3.97%	1.59%	2.38%	1.59%	1.59%	39.68%
58-67	30.00%	13.33%	16.67%	5.00%	0.00%	5.00%	6.67%	8.33%	1.67%	1.67%	1.67%	10.00%
68+	22.22%	22.22%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	44.44%

Gender	Asthma & other respiratory problems	Cancer	Allergies & hay fever	Body irritation	Child health problems and birth defects	Physiological & physical health problems	Cardiovascular problems	Headaches	Mental & psychological health problems	Immunity problems	Others	Blank and/or invalid replies
Female	26.41%	10.88%	10.59%	3.95%	0.56%	2.68%	3.67%	2.97%	1.98%	1.41%	0.99%	33.90%
Male	25.67%	12.07%	7.47%	2.68%	0.57%	5.56%	3.26%	2.49%	2.87%	1.92%	1.34%	34.10%
Prefer not to answer	33.33%	16.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.67%	33.33%

Home Locality	Asthma & other respiratory problems	Cancer	Allergies & hay fever	Body irritation	Child health problems and birth defects	Physiological & physical health problems	Cardiovascular problems	Headaches	Mental & psychological health problems	Immunity problems	Others	Blank and/or invalid replies
Attard	30.95%	11.90%	4.76%	9.52%	0.00%	4.76%	2.38%	2.38%	2.38%	0.00%	0.00%	30.95%
Balzan	25.00%	8.33%	8.33%	0.00%	0.00%	8.33%	8.33%	0.00%	0.00%	8.33%	0.00%	33.33%
Birgu	33.33%	22.22%	11.11%	0.00%	0.00%	11.11%	11.11%	11.11%	0.00%	0.00%	0.00%	0.00%
Birkirkara	28.57%	15.87%	12.70%	1.59%	0.00%	3.17%	0.00%	3.17%	0.00%	0.00%	0.00%	34.92%
Birzebbuga	33.33%	16.67%	16.67%	0.00%	0.00%	0.00%	0.00%	5.56%	5.56%	5.56%	0.00%	16.67%
Bormla	33.33%	0.00%	11.11%	11.11%	0.00%	11.11%	11.11%	0.00%	0.00%	0.00%	0.00%	22.22%
Dingli	33.33%	0.00%	22.22%	0.00%	0.00%	11.11%	11.11%	0.00%	11.11%	0.00%	0.00%	11.11%
Fgura	24.24%	9.09%	15.15%	0.00%	0.00%	6.06%	0.00%	3.03%	6.06%	0.00%	0.00%	36.36%
Floriana	33.33%	22.22%	22.22%	0.00%	11.11%	0.00%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%
Gharghur	28.57%	14.29%	4.76%	0.00%	0.00%	0.00%	4.76%	0.00%	0.00%	0.00%	9.52%	38.10%
Ghaxaq	33.33%	6.67%	13.33%	6.67%	0.00%	0.00%	6.67%	6.67%	0.00%	0.00%	6.67%	20.00%
Gudja	26.67%	13.33%	0.00%	6.67%	0.00%	0.00%	0.00%	0.00%	6.67%	0.00%	0.00%	46.67%
Gzira	33.33%	6.67%	13.33%	0.00%	0.00%	13.33%	13.33%	0.00%	6.67%	6.67%	0.00%	6.67%
Hamrun	27.78%	16.67%	11.11%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.56%	27.78%
Iklin	20.00%	20.00%	0.00%	6.67%	6.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	46.67%
Isla	33.33%	11.11%	22.22%	0.00%	0.00%	11.11%	22.22%	0.00%	0.00%	0.00%	0.00%	0.00%
Kalkara	25.00%	8.33%	8.33%	8.33%	0.00%	0.00%	0.00%	8.33%	0.00%	0.00%	0.00%	41.67%
Kirkop	25.00%	16.67%	16.67%	0.00%	0.00%	0.00%	25.00%	8.33%	0.00%	0.00%	0.00%	8.33%
Lija	25.00%	25.00%	16.67%	8.33%	0.00%	0.00%	0.00%	8.33%	0.00%	8.33%	0.00%	8.33%
Luqa	22.22%	5.56%	16.67%	0.00%	0.00%	11.11%	5.56%	0.00%	0.00%	0.00%	0.00%	38.89%
Marsa	33.33%	16.67%	8.33%	0.00%	0.00%	0.00%	16.67%	8.33%	8.33%	0.00%	0.00%	8.33%
Marsaskala	27.27%	12.12%	12.12%	3.03%	6.06%	0.00%	0.00%	6.06%	0.00%	6.06%	0.00%	27.27%
Marsaxlokk	20.83%	12.50%	0.00%	0.00%	0.00%	8.33%	4.17%	0.00%	0.00%	4.17%	4.17%	45.83%
Mdina	33.33%	16.67%	5.56%	5.56%	5.56%	0.00%	5.56%	11.11%	0.00%	0.00%	0.00%	16.67%
Mellieha	33.33%	22.22%	7.41%	11.11%	0.00%	0.00%	7.41%	0.00%	0.00%	0.00%	0.00%	18.52%
Mgarr	20.00%	20.00%	13.33%	0.00%	0.00%	13.33%	0.00%	0.00%	0.00%	0.00%	0.00%	33.33%

Mosta	20.37%	9.26%	5.56%	7.41%	0.00%	3.70%	3.70%	1.85%	0.00%	3.70%	1.85%	42.59%
Mqabba	20.00%	13.33%	6.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	60.00%
Msida	25.00%	11.11%	5.56%	5.56%	0.00%	8.33%	0.00%	2.78%	5.56%	0.00%	0.00%	36.11%
Mtarfa	13.33%	13.33%	6.67%	0.00%	0.00%	0.00%	6.67%	0.00%	0.00%	0.00%	0.00%	60.00%
Naxxar	25.00%	4.17%	0.00%	4.17%	4.17%	8.33%	4.17%	0.00%	4.17%	0.00%	0.00%	45.83%
Paola	33.33%	13.33%	26.67%	13.33%	0.00%	0.00%	0.00%	6.67%	0.00%	0.00%	0.00%	6.67%
Pembroke	22.22%	11.11%	11.11%	11.11%	0.00%	0.00%	0.00%	11.11%	0.00%	0.00%	0.00%	33.33%
Pieta'	11.11%	22.22%	11.11%	22.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	33.33%
Qormi	24.24%	18.18%	15.15%	0.00%	0.00%	0.00%	0.00%	3.03%	0.00%	0.00%	0.00%	39.39%
Qrendi	16.67%	16.67%	25.00%	8.33%	8.33%	0.00%	8.33%	8.33%	8.33%	0.00%	0.00%	0.00%
Rabat	28.57%	0.00%	14.29%	4.76%	0.00%	0.00%	4.76%	0.00%	0.00%	9.52%	9.52%	28.57%
Safi	16.67%	0.00%	0.00%	0.00%	0.00%	8.33%	0.00%	0.00%	0.00%	0.00%	8.33%	66.67%
San Gwann	27.27%	21.21%	0.00%	3.03%	0.00%	6.06%	6.06%	0.00%	6.06%	0.00%	0.00%	30.30%
Santa Lucija	22.22%	11.11%	16.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.56%	44.44%
Santa Venera	25.00%	20.83%	4.17%	0.00%	0.00%	8.33%	0.00%	0.00%	12.50%	0.00%	0.00%	29.17%
Siggiewi	25.00%	11.11%	8.33%	2.78%	0.00%	0.00%	2.78%	0.00%	8.33%	5.56%	0.00%	36.11%
Sliema	25.64%	2.56%	5.13%	5.13%	0.00%	7.69%	2.56%	2.56%	2.56%	2.56%	0.00%	43.59%
St. Julian's	28.57%	9.52%	7.14%	2.38%	0.00%	11.90%	4.76%	2.38%	9.52%	2.38%	2.38%	19.05%
St. Paul's Bay	23.19%	8.70%	7.25%	0.00%	0.00%	4.35%	0.00%	4.35%	1.45%	5.80%	1.45%	43.48%
Swieqi	25.00%	5.56%	5.56%	0.00%	0.00%	0.00%	0.00%	2.78%	0.00%	0.00%	2.78%	58.33%
Ta' Xbiex	33.33%	8.33%	8.33%	0.00%	0.00%	0.00%	16.67%	0.00%	8.33%	0.00%	8.33%	16.67%
Tarxien	20.83%	4.17%	4.17%	0.00%	0.00%	4.17%	4.17%	4.17%	4.17%	4.17%	0.00%	50.00%
Valletta	33.33%	22.22%	22.22%	0.00%	0.00%	11.11%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%
Xghajra	33.33%	33.33%	16.67%	0.00%	0.00%	0.00%	0.00%	8.33%	0.00%	0.00%	0.00%	8.33%
Zabbar	28.21%	7.69%	7.69%	2.56%	0.00%	0.00%	5.13%	2.56%	0.00%	0.00%	0.00%	46.15%
Zebbug	29.63%	11.11%	7.41%	0.00%	0.00%	0.00%	3.70%	0.00%	0.00%	0.00%	0.00%	48.15%
Zejtun	19.05%	0.00%	14.29%	4.76%	0.00%	4.76%	0.00%	4.76%	0.00%	0.00%	0.00%	52.38%
Zurrieq	26.67%	2.22%	11.11%	6.67%	0.00%	6.67%	4.44%	6.67%	2.22%	0.00%	2.22%	31.11%
Occupation	**Asthma & other respiratory problems**	**Cancer**	**Allergies & hay fever**	**Body irritation**	**Child health problems and birth defects**	**Physiological & physical health problems**	**Cardiovascular problems**	**Headaches**	**Mental & psychological health problems**	**Immunity problems**	**Others**	**Blank and/or invalid replies**
Employed	25.24%	11.99%	9.34%	3.21%	0.56%	4.32%	2.23%	2.79%	2.51%	1.39%	1.26%	35.15%
Retired	28.89%	15.56%	13.33%	2.22%	0.00%	2.22%	8.89%	4.44%	0.00%	0.00%	0.00%	24.44%
Self-employed	31.11%	8.89%	13.33%	4.44%	0.00%	6.67%	6.67%	2.22%	2.22%	6.67%	0.00%	17.78%
Student	28.13%	11.11%	7.29%	3.47%	0.69%	2.78%	3.82%	1.74%	3.13%	1.39%	1.39%	35.07%
Taking care of a family and/or a house	26.67%	9.52%	12.38%	4.76%	0.95%	3.81%	7.62%	4.76%	0.95%	1.90%	1.90%	24.76%
Unemployed	16.67%	5.56%	2.78%	2.78%	0.00%	2.78%	2.78%	2.78%	0.00%	2.78%	0.00%	61.11%
Level of education	**Asthma & other respiratory problems**	**Cancer**	**Allergies & hay fever**	**Body irritation**	**Child health problems and birth defects**	**Physiological & physical health problems**	**Cardiovascular problems**	**Headaches**	**Mental & psychological health problems**	**Immunity problems**	**Others**	Blank and/or invalid replies
Others	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%

Post-Graduate	28.27%	12.53%	9.87%	4.00%	0.80%	4.80%	3.47%	1.33%	1.60%	2.40%	0.53%	30.40%
Post-Secondary	26.42%	10.98%	6.91%	2.85%	1.22%	3.66%	4.07%	4.07%	2.85%	2.03%	0.81%	34.15%
Primary	33.33%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%
Secondary	21.97%	11.36%	10.61%	2.27%	0.00%	3.03%	8.33%	2.27%	0.76%	0.00%	0.76%	38.64%
Tertiary	25.58%	10.90%	9.43%	3.56%	0.21%	3.56%	1.89%	3.14%	3.14%	1.26%	2.10%	35.22%

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